SEPTA

SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY

STREETCAR TECHNICAL SPECIFICATION

SEPTA NEW RAIL VEHICLE ENGINEERING

March 2022

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SEPTA

Table of Contents

1.1 Scope

This Section includes requirements that apply to every section in the Specifications.

1.2 General Requirements

The vehicles shall be modern, articulated, low-floor Streetcars, designed to be safe, reliable, and maintainable.

The Contractor shall have the following responsibilities:

1. Design, manufacture, test, and deliver the products as described by the Technical Specifications ("the Specifications"). Deviations from these requirements are permitted only with specific written **approval** of the Engineer, as specified in the Contract Documents.
2. Design and integrate vehicle systems such that specified requirements are achieved without conflict or error within or between onboard systems and between vehicle systems and wayside systems.
3. Ensure that designers, suppliers, and subcontractors are informed of specified requirements and that appropriate engineering management tools are used to ensure that coordination and communication occurs between the designers of inter-related systems.

1.3 Specifications

1.3.1 Introduction

The Specifications define the functional, performance, and interface design requirements for the vehicles and Contract-required support systems.

1.3.2 Organization

The Specifications are divided into sections according to technical discipline and traditional supplier arrangements.

1. The format is for convenience only and does not imply or suggest a preferred system integration approach.
2. Explicit references may appear within sections linking requirements appearing in other sections. Such references shall, in no way, be assumed to limit the range or applicability of the requirements in this document, whether referenced or not.

1.3.3 Language

The Specifications are written in imperative mood and streamlined form:

1. Imperative language is directed to the Contractor, although work may be carried out by a subcontractor or supplier under the Contractor's direction. The words "shall be" are included by inference where a colon (:) is used within sentences or phrases.

2. Examples:

    a. "Perform type tests at the manufacturer's facilities unless indicated otherwise in the Specifications," means that Contractor is responsible for type tests being performed, whether by itself or by its subcontractor.

    b. "Comply with the following:" means that Contractor shall incorporate the requirements listed after this statement into its design and manufacture of the vehicle.

    c. "Stress Analysis Report: Submit minimum 60 days before starting manufacture of vehicle body structural parts" means that Contractor shall submit the report within the time indicated.

    d. "Life expectancy: Minimum 100,000 hours" means that the life expectancy of the component shall be minimum 100,000 hours.

1.3.4 Contract Deliverables

Comply with the following:

1. Mandatory:

    a. The Specifications require submittal of the following Contract deliverables for review by the Engineer to verify compliance with specified requirements, and for after-delivery support of the vehicles:

        - Contract Deliverable Requirements List items (CDRLs), which include drawings, documents, analyses, technical data, test procedures and results, manuals, schedules, and similar. These are listed at the end of each section under the heading Contract Deliverables Requirements List.
        - Design review packages.
        - Samples.
        - Mock-ups.
        - Pilot vehicle

1.3.5 Alternate Design Proposals

1. The Specifications include statements allowing alternate designs, products, and standards to be proposed and submitted for **approval**.

2. If the Contractor chooses to propose one of these alternate designs, products, or standards, it shall be submitted to the Engineer for review and **approval**, whether this is stated or not, and is subject to **approval** before it may be used.

3. The submittal package shall include a detailed comparison of the features, functions, and performance parameters for the specified design, product, or standard and for the proposed alternate.

4. Unless otherwise noted in the Contract Documents, each item specified for submittal shall be both reviewed and **approved** by the Engineer, whether this is specifically stated or not.

5. The Engineer reserves the right to request additional drawings, documents, analyses, technical data, test procedures and results, or similar information, as required to clarify and amplify the intent of Contract deliverables submitted.

1.4 Access to Contractor Facilities

SEPTA and its authorized representatives shall have the right to visit facilities of the Contractor and its subcontractors:

1. Visits are to assess progress, monitor work being performed, conduct QA/QC audits, conduct quality inspections, and witness testing.

2. SEPTA and its authorized representatives shall have the right to photograph, at its expense, any or all phases of vehicle or equipment construction, including subcontractor work.

1.5 Materials and Equipment

Name brands, specific equipment, or specific materials may be referenced in the Specifications:

1. Such equipment has been shown to be successful in previous applications, where correctly applied and integrated with other equipment; however, such references shall not be interpreted as pre- **approval** of Contractor designs or applications.

2. The Contractor is responsible for the selection, application, and integration of equipment and materials as necessary to conform to the specified requirements.

Equipment provided under this Contract shall be new:

1. Rebuilt or refurbished equipment is prohibited.

2. New equipment damaged during performance of this Contract may be restored to new condition only where **approved** on a case-by-case basis, and restorations, including a complete series of inspections and routine tests, shall be performed by the original equipment manufacturer.

1.6 Industry Standards and Regulations

Comply with the following:

1. Where standards, codes, or reference books are referenced in the Specifications, use the most current version available at the time of Notice to Proceed (NTP), unless otherwise noted.

2. Where laws, statutes, or regulations are specified, such as the Code of Federal Regulations (CFR), use the version in force at the time of NTP.

3. References to laws, statutes, or regulations are included in the Specifications to aid the Contractor. Whether referenced or not, all applicable federal, state, and local laws, statutes, and regulations shall be included in this Contract.

1.7 Americans With Disabilities Act (ADA)

The Americans with Disabilities Act (ADA) prohibits discrimination on the basis of disability in the provision of transportation services by public and private entities:

1. The Department of Transportation (DOT) issues legally enforceable regulations to implement the transportation provisions of the ADA, codified in 49 CFR Parts 37 and 38, and compliance with these regulations is mandatory whether referenced in the Specifications or not.

2. Compliance with interpretations by the Federal Transit Administration (FTA) in Administrators Policy Letters is also mandatory.

References are furnished to these parts in the Specifications:

1. 49 CFR 38: Technical requirements for vehicles are primarily found in this part.

2. 36 CFR 1191, Appendix D: Adopted by DOT in 49 CFR 37, Appendix A, by reference with some modifications. In some cases, requirements from this part are applied to vehicles.

1.8 System of Units

International System of Units (SI) units are shown with United States customary units following in parentheses:

1. Rounding: If a difference exists between SI and U.S. customary units due to rounding, SI units shall be primary.

2. Exception: Where laws, statutes, or regulations give dimensions only in U.S. customary units, the U.S. customary units shall be primary.

1.9 English Language

Communication with SEPTA and its authorized representatives shall be conducted in the English language only, including but not limited to meetings, correspondence, Contract deliverables, other documents submitted to SEPTA and all Work Product produced under the Contract.

1.10 Definitions

The following terms may appear in this document. They are defined as indicated, whether capitalized or not:

Acceleration, Average: The arithmetic difference between ending speed and initial speed, divided by the time elapsed between those speeds. See Section 15, Testing, for measurement method.

Acceleration, Instantaneous: The value of acceleration at a specific instance of time, or speed.

Accelerometer: An inertial device used to measure the rate of change of acceleration.

Adhesion, Coefficient of: During rolling contact, the ratio between the tangential force at the wheel-rail interface and the normal force.

Alignment, Track: The horizontal components of track geometry.

Approval: Acceptance in writing by SEPTA or SEPTA's Engineer. In no instance will an **approval** by SEPTA constitute an authorization to deviate from Contract requirements. Any deviation from Contract requirements must be accomplished by amendment to the Contract. In addition, no **approval** by SEPTA will constitute a waiver of SEPTA’s right to later require compliance with Contract requirements and the correction of Defects.

Approved or Approved Type: CDRL, design, type material, procedure, design standard, standards body, media, or method given **approval** by SEPTA or SEPTA's authorized representative.

Assembly: A number of parts or subassemblies or any combination thereof joined together to perform a specific function and capable of disassembly.

Auxiliary Power System: The system including an auxiliary ac inverter for ac auxiliary loads and a dc LVPS for low-voltage dc auxiliary loads.

Auxiliary loads: Loads other than propulsion, such as lighting and HVAC.

AW0: Weight of empty vehicle.

AW1: Weight of vehicle with a full seated load, including one Operator.

AW2: Weight of vehicle with a full seated load, including one Operator, plus standees at four passengers/m^2.

AW3: Weight of vehicle with a full seated load, including one Operator, plus standees at six passengers/m^2.

AW4: Weight of vehicle with a full seated load, including one Operator, plus standees at eight passengers/m^2.

Back Shop: SEPTA maintenance facility where component-level maintenance work is performed on vehicle equipment in a specialized environment. The crafts represented in these shops are typically furthered specialized and are representative of the specific equipment they are working on.

Blending: In braking, the simultaneous control of dynamic (rheostatic and regenerative) and friction braking, with the effort of each continuously proportioned to achieve the required total braking effort within the specified tolerances.

Brake Assurance: The process of monitoring brake performance following a full service brake application initiated by vehicle-borne ATP and Train Control System command.

Burn-In: Operating a component, system, or device in a test mode, often in an extreme or cycled temperature environment, for a specified period of time or distance, to confirm reliable operation.

Cab Make-Up: The condition of cab activation and selected direction of travel for each Operator's cab.

Cab Signal: Speed commands generated by the wayside signaling system and inductively received through the vehicle-borne ATP and Train Control System track receivers.

Car House: SEPTA maintenance facility where running maintenance work is performed on the vehicle, which typically requires less than 8 hours of labor. The crafts represented in these shops are typically Vehicle Specialists and General Mechanics.

Car Shop: SEPTA maintenance facility where heavy maintenance work is performed on the vehicle, which typically requires more than 8 hours of labor. The crafts represented in these shops are more specialized for the level of work encountered.

Coast: The mode of operation in which no propulsion or braking efforts are in effect, except for normal drivetrain losses.

Component: Portions of equipment not typically repaired or disassembled, such as nuts, bolts, resistors, fittings, single-piece castings. Used interchangeably with "parts."

Component-Level Maintenance: Maintenance completed on a specific component, usually completed by a specialist.

Contract Deliverables Requirements List (CDRL): List of select documents and other deliverable items that the Contractor is required to deliver to SEPTA. CDRL is also used to refer to a specific item on the list.

Contract Drawings: Drawings and Specifications furnished by SEPTA as part of this procurement.

Contractor: The person or persons, firm, partnership, corporation, or combination thereof that has entered into the procurement Contract with SEPTA to supply the vehicles.

Contractor's Drawings: Items such as general drawings, detail drawings, graphs, diagrams, sketches, calculations, and catalog cuts prepared by the Contractor for use in its manufacturing facility, assembly facility, or shop, to fabricate, assemble, and install parts of the vehicle whether manufactured by it from raw materials or purchased from others in a ready-to-use condition.

Coupler: The mechanism used to connect rolling stock in a train.

Curve, Track: Track having a constant horizontal circular radius.

Data: Written presentations, plans, reports, schedules, forms, drawings, calculations, analyses, procedures, samples, photos and other items prepared by the Contractor, it subcontractors, or suppliers in response to requests from SEPTA or its authorized representative or to otherwise meet the requirements of the Contract Documents.

Days: Unless otherwise designated, days as used in the Contract Documents will be understood to mean calendar days; that is, including weekends and holidays.

Days, Working: Those calendar days during which regular business is conducted, excluding Saturdays, Sundays, and Federal, State, and municipal holidays that are observed by SEPTA.

Decelerometer: An inertial device used to measure braking effort.

Defect(s), Defective: A condition that does not meet the requirements of the Contract Documents; causes a vehicle or a portion of the work to cease operation or to operate in a degraded mode; or inflicts injury or damage to a vehicle, the work, other property, or persons.

Drive: A system consisting of one or several motors or actuators, their direct power control equipment, and the associated mechanical devices required to produce a useful output.

Dynamic Braking: Braking effort produced by using the traction motors as generators, dissipating vehicle energy by rheostatic braking, regenerative braking, or a combination of both.

Engineer: SEPTA's designated Program Manager or designated representative authorized by the Program Manager. May also refer to a representative or representatives of the Engineer.

Equal: Providing the same function, performance, and reliability.

Failsafe: A system is "failsafe" when it is designed such that a malfunction will not cause the system to achieve an unsafe state.

Failure: A condition in which equipment does not function as specified, designed, or expected.

Failure Rate: The frequency of failure, expressed as failures per hour or failures per mile. Failure rate is the mathematical reciprocal of Mean Time Between Failures (MTBF) or Mean Distance Between Failures (MDBF).

First Article: The first item of production that fixes and defines each subsequent production item. First articles are production units intended for review by SEPTA.

Fleet Management Plan: The FTA required management plan includes an inventory of all Streetcars among other items, such as operating policies, peak vehicle requirements, maintenance and overhaul programs, system and service expansions, rolling stock procurements and related schedules, and spare ratio justification.

Frog (Turnout or Crossing): Device made of rail sections, castings, or both, arranged to permit a wheel on one rail to cross over another rail on an intersecting track.

Furnish: To supply and deliver to project site.

Gauge, Track: Distance between running rails, measured 15.88 mm (5/8 in) below the top of rail.

Grab handle: A safety device mounted on the aisle-side corner of a seat and designed to be grasped by the hand to enable a person to maintain balance.

Grab rail: A horizontal safety device mounted across the back of a seat and designed to be grasped by the hand to enable a person to maintain balance.

Heavy Repair Maintenance: Maintenance that requires holding a vehicle out of service due to the longer time required to complete the work and includes maintenance tasks scheduled for three-year or greater intervals that are associated with vehicle and equipment overhaul.

Handhold: A vertical safety device mounted to a wall or other vertical surface and designed to be grasped by the hand to enable a person to maintain balance.

Handrail: A horizontal safety device mounted to a wall or windscreen or hung from the ceiling and designed to be grasped by the hand to enable a person to maintain balance.

Hotel loads: The same as auxiliary loads (see definition above).

Inspector: The person(s) or firm designated by SEPTA as its quality control representative.

Install: To place in position for service or use.

Interface: The points where two or more systems, subsystems, components, or structures meet, and transfer energy or information.

Jerk: Time rate of change of acceleration and deceleration, equal to the second derivative of velocity.

Liner (as in interior liner): The visible covering material for the walls, ceiling, and other interior surfaces.

Line Voltage: The voltage at the vehicle measured between the OCS and the running rails.

Load Weighing: The measurement of passenger load for the purpose of adjusting tractive effort to produce a constant acceleration or braking rate regardless of load.

Lowest Level Replaceable Unit (LLRU): The lowest unit (component) of a system or subsystem, which is removable and replaceable from an installed position by standard attachments (e.g., by bolts and nuts or quick-disconnects). This definition is dependent upon the location of the equipment relative to where maintenance is being performed.

Manufacturer: The builder or producer supplying materials, equipment, or apparatus for installation on the vehicle.

Mask, Window: Interior liner that surrounds the windows, often molded to include the sill and other portions of the sash.

Mean Distance Between Failures (MDBF): The mean operating mileage between independent failures.

Mean Time Between Failures (MTBF): The mean operating time between independent failures. This is a fleet level statistic, not applied to individual vehicles.

Mean-Time-To-Repair (MTTR): The average time required to repair a failed component or device.

Mode Change Dead Time (MCDT): The time for a system to fully cease one state and initiate a second state, as commanded. The full MCDT is measured from the time an operating mode change is given, until 10% of the newly commanded acceleration rate is reached. If the newly commanded rate is coast, the last commanded effort shall be reduced following the specified maximum jerk rate.

Nominal, as in “nominal voltage”: Exists in name only, not implying an actual operating value.

No Motion Speed: The lowest speed detectable by the vehicle control systems.

Normal, as in “normal operating conditions” or “operating normally”: A condition in which relevant vehicle equipment is not in a failure mode and the environment is functioning as specified.

Overspeed Protection: The process of vitally assuring that the vehicle speed does not exceed the speed limit.

Part: See Component, above.

Project: The Vehicle Project as described and defined in Section 1 of the Request for Proposals in the Contract Documents.

Proof (used as a suffix), as in “splashproof” or “dustproof”: The device and contents are impervious to, or unharmed by, application of the indicated action or material.

Provide: To design, furnish, and install, complete and ready for intended use.

Regenerative Braking: Electrical energy produced by motors acting as generators, putting electrical power onto the distribution system for use by other equipment.

Reliability: The probability of performing a specified function, without failure and within design parameters, for the period of time indicated.

Restraining Rail: Rail used in sharp horizontal curves to restrain the wheels away from the outer rail. The restraining rail is mounted adjacent to the inside rail and contacts the back of inside wheel flange.

Rheostatic Braking: Electrical energy produced by motors dissipated as heat in resistors.

Running Repair Maintenance: Maintenance that can be completed in less than 8 hours of labor, typically, which includes routine maintenance, cleaning, light inspections, and troubleshooting, etc.

Safe: Free from unreasonable risk of harm, injury, or danger.

Safety: The condition in which persons are free from unreasonable risk of danger, harm, or loss arising from the design, manufacture, assembly, malfunction, or failure of the vehicle or any of its components or systems.

SEPTA: The party with whom the Contractor has executed the Contract or the authorized representative of the party with whom the Contractor has executed the Contract.

Service, as in “service use” or “service braking”: The operation of the vehicles under normal conditions.

Service proven design:

Unless otherwise specifically defined with respect to a particular system or subsystem, "service proven" means the following:

1. Systems and subsystems:
    a. Used in revenue rail operation for at least three years; and
    b. Used in revenue rail operation for at least 1 million vehicle miles with at least 75 thousand miles per vehicle (i.e., 25 thousand miles per year per vehicle); and

   c. Has a minimum fleet size of 12 vehicles.

2. Complete vehicle:

   a. Used in revenue rail operation for at least two years; and

   b. Has a minimum operating fleet size of six vehicles.

Set: A unit or units and necessary assemblies, subassemblies, and parts connected together or used in association to perform an operational function.

Shall: Denotes a mandatory specification or requirement.

Shop: SEPTA's vehicle maintenance facility.

Simulated Revenue Service: Operation of a vehicle through the Project alignment, stopping at each station and cycling the doors at each station stop.

Slide, Wheel: During braking, the condition existing when the rotational speed of the wheel is less than that for pure rolling contact between tread and rail.

Software Configuration Item: An aggregation of work products that is designated for configuration management and treated as a single entity in the configuration management process.

Speed:

1. Balancing Speed: The speed attained by the vehicle when resisting forces exactly equal the maximum available tractive forces.

2. Base Speed: The speed to which the maximum constant acceleration can be maintained at the nominal line voltage.

3. Civil Speed: The operating speed limit assigned to each track segment.

4. Maximum Operating Speed: The maximum speed at which the vehicle will be operated in normal service.

5. Schedule Speed: The average speed of a vehicle, from terminal-to-terminal, obtained by dividing the distance between these points by the time taken to make the trip, including time for intermediate station stops.

6. Vehicle Design Speed: The speed at which the vehicle can operate continuously without damage to equipment, independent of any speed limits imposed by vehicle controls.

Spin, Wheel: During acceleration, the condition existing when the rotational speed of the wheel is greater than that for pure rolling contact between tread and rail.

Stanchion: A vertical safety device mounted to the floor and ceiling or from top of seat back or seat back grab rail to the ceiling and designed to be grasped by the hand to enable a person to maintain balance.

Stop, Emergency: The stopping of a vehicle by an emergency brake application.

Stop, Service: The stopping of a vehicle by application of service braking.

Subassembly: A collection of components used to perform a distinct function, usually in conjunction with other subassemblies and components, as part of a larger system. Subassemblies are usually replaceable as units, such as circuit boards, bearings, and valves.

Subsystem: A combination of sets, groups, etc., which performs an operational function within a system and is a major subdivision of the system.

Superelevation, Track: The difference in elevation (height) between the top surfaces of the high and low rails on a curved segment of track.

System: A combination of two or more sets, which may be physically separated when in operation, and such other assemblies, subassemblies, and parts necessary to perform an operational function or functions.

Tangent Track: Straight track having no horizontal curvature.

Tight (used as a suffix), as in “watertight” or “airtight”: Enclosed or protected so as to completely exclude the indicated material from passage.

Time, Build-Up: In response to a step-forcing function (as in control signal), time interval from 10% of the total change in value to the attainment of 90% of the total change in value of the controlled variable. Build-up time is equal to response time minus dead time.

Time Constant: Slope of controlled variable build-up curve in units of controlled variable per unit of time, measured during the build-up time interval.

Time, Dead (also Time, Reaction): Time from the occurrence of a step change of the control signal to the attainment of 10% of the total change in value of the controlled variable.

Time, Down: The time during which equipment is not capable of doing useful work because of maladjustment, malfunction, or maintenance in progress.

Time, Response: Time from the occurrence of a step change of control signal to the attainment of 90% of the total change in value of the controlled variable.

Time, Warm-up: The elapsed time from the application of power to an operable device until it is capable of performing its intended function.

Tolerance: The total amount a specific dimension is permitted to vary, indicated either as plus or minus values or as a maximum value.

Tow Bar: A mechanical bar used to couple two cars

Traction System: The system of wheels, motors, gears, brakes, axles, direct controls, and appurtenances that propels or retards a vehicle in response to control signals.

Train: Any number of vehicles, from one to the maximum, coupled together and moving as one.

Tram: “In tram” is the condition of ideal truck geometry in which the axles are perfectly parallel and the wheels are in perfect longitudinal alignment. The centers of the journal bearings represent the corners of a perfect rectangle. Verification that a truck is “in tram” is determined by measuring the diagonal and longitudinal distance between reference points on the axle bearing housings.

Truck: An assembly of structural frame, with axles and four wheels, associated motors, gear units, friction brake components, magnetic track brakes, safety bars, and suspension elements that supports a portion of the vehicle weight. Also known as a Bogie.

TWC: Train to Wayside Communications — ability for each major system to communicate over the car and wayside network systems.

Vehicle: A complete assembly as described by the Specifications, ready to operate.

Vital: A term applied to a device or circuit that has known failure modes, certain of which occur with extreme rarity.

Wainscot: The lower portion of a wall, especially if finished differently from the upper portion.

Warp, Track: The vertical distance between the plane of any three of four rail head contact points (two on each rail) forming a rectangle and the remaining point.

Warp (Short), Track: Warp occurring within a distance of _____ m (___ ft).

Wheelset: An assembly that includes an axle and two wheels or, for stub-axle designs, two laterally opposed wheels and their associated stub axles.

Yard: SEPTA’s vehicle storage yard.

1.11 Acronyms and Abbreviations

The following acronyms and abbreviations may appear in this document. They are defined as indicated:

AAR	Association of American Railroads
ACGIH	American Conference of Governmental Industrial Hygienists
ADA	Americans with Disabilities Act
ADS	Appraisal Disclosure Statement
ADU	Aspect Display Unit
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ALG	Application Layer Gateway
ANSI	American National Standards Institute
AOCP	Accessible On-Board Circulation Path
APC	Automatic Passenger Counter

API	Application Programming Interface
APIS	Automatic Passenger Information System
APTA	American Public Transportation Association
AQL	Acceptance Quality Limit
ARP	Address Resolution Protocol
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASIC	Application Specific Integrated Circuit
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATP	Automatic Train Protection
AVL	Automatic Vehicle Locator
AWG	American Wire Gauge
AWS	American Welding Society
BAFO	Best and Final Offer
BCU	Braking Control Unit
BTE	Bench Test Equipment
CBTC	Communications Based Train Control
CCP	Configuration Control Plan
CEM	Crash Energy Management
CCT	Correlated Color Temperature
CCTV	Closed Circuit Television
CDR	Conceptual Design Review
CDRL	Contract Deliverables Requirements List
CD-ROM	Compact Disc Read-Only Memory
CDS	Central Diagnostic System
CEM	Crash Energy Management
CFR	Code of Federal Regulations
CGHAZ	Coarse Grain Heat Affected Zone
CMMI	Capability Maturity Model Integration

CMMI-DEV	CMMI for Development
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial Off-The-Shelf
CPLD	Complex Programmable Logic Device
CTFD	Cab and Train Functional Description
CVE	Common Vulnerabilities and Exposures
CVN	Charpy V Notch
DB	Dry Bulb
DBDD	Database Design Description
DBTT	Ductile-to-Brittle Transition Temperature
DHCP	Dynamic Host Configuration Protocol
DIN	Deutsche Industrie Norm (German Industrial Standard)
DOI	Distinctiveness of Image
DST	Daylight Saving Time
DUT	Device Under Test
DVR	Digital Video Recorder
EB	Emergency Brake
ECN	Ethernet Consist Network
ECR	Engineering Change Request
ECU	Electronic Control Unit
EEPROM	Electrically Erasable Programmable Read-Only Memory
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EN	European Norm (European Standards)
EPROM	Erasable Programmable Read-Only Memory
ETB	Ethernet Train Backbone
FAA	Federal Aviation Administration
FAI	First Article Inspection
FCC	Federal Communications Commission
FD	Functional Description

FDR	Final Design Review
FEA	Finite Element Analysis
FMECA	Failure Mode, Effects, and Criticality Analysis
FPGA	Field Programmable Gate Array
FRA	Federal Railroad Administration
FRP	Fiber-Reinforced Plastic, or Polymer
FSB	Full Service Brake
FTA	Federal Transit Administration
FTPS	File Transfer Protocol Secure
GPS	Global Positioning System
GUI	Graphical User Interface
HAZ	Heat-Affected Zone
HD	High Definition
HDD	Hard Disk Drive
HPCU	Hydraulic Pressure Control Unit
HSCB	High Speed Circuit Breaker
HSLA	High-Strength Low-Alloy (Steel)
HTTPS	Hypertext Transfer Protocol Secure
HVAC	Heating, Ventilating, and Air Conditioning
ICD	Interface Control Document
ICEA	Insulated Cable Engineers Association
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	internet Engineering Task Force
IFI	Industrial Fastener Institute
IGBT	Insulated-Gate, Bipolar Transistor
INCOSE	International Council on Systems Engineering
IP	Internet Protocol
IPDR	In-Process Design Review

I/O	Input/Output
ISO	International Organization for Standardization
JIC	Joint Industrial Council
JSON	JavaScript Object Notation
JTAG	Joint Test Action Group
LDTS	Local Diagnostic and Test System
LED	Light Emitting Diode
Li-Ion	Lithium-Ion
LLRU	Lowest Level Replaceable Unit
LRU	Line Replaceable Unit
LRV	Light Rail Vehicle
LVPS	Low-Voltage Power Supply
max	maximum
MB	Maximum Brake
MC	Master Controller
MCDT	Mode Change Dead Time
MDN	Monitoring and Diagnostics Network
MDS	Monitoring and Diagnostic System
MDT	Mobile Data Terminal
MIL	U.S. Military Specification
min	minimum
MOV	Metal Oxide Varistor
MS	Margin of Safety
MDBF	Mean Distance Between Failures
MSSQL	Microsoft Structured Query Language
MTBF	Mean Time Between Failure
MTP	Master Test Plan
MTTR	Mean Time to Repair
NBS	National Bureau of Standards
NCR	Non-Conformance Report

NDT	Nil-Ductility Temperature
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NFL	No Field Lubrication
NFPA	National Fire Protection Association
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride
NIST	National Institute of Standards and Technology
NIT	Network Integration Test
NTP	Notice to Proceed
OCS	Overhead Contact System
OEM	Original Equipment Manufacturer
OIL	Open Items List
OS	Operating System
OSI	Open Systems Interconnection
OWLS	One-Way Low-Speed
PA	Public Address
PCN	Propulsion Control Network
PDR	Preliminary Design Review
PDST	Programmable Device Summary Table
PENNDOT	Pennsylvania Department of Transportation
PI	Passenger Intercom, Proportional Integral (control)
PID	Proportional Integral Derivative (control)
PIV	Peak Inverse Voltage
PMTTR	Predicted Mean Time to Repair
ppm	parts per million
PQR	Procedure Qualification Record
PROM	Programmable Read Only Memory
PTU	Portable Test Unit
PWM	Pulse Width Modulation

QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QCIP	Quality Control and Inspection Plan
RAM	Random Access Memory
RAMS	Reliability, Availability, Maintainability, and Safety
RF	Radio frequency
RFC	Request for Comments
RFI	Radio frequency interference, Request for Information
RFP	Request for Proposal
rms	root mean square
ROW	Right of Way
RSTP	Rapid Spanning Tree Protocol
SAE	Society of Automotive Engineers
SBOM	Software Bill of Materials
SCAMPI	Standard CMMI Appraisal Method for Process Improvement
SCI	Software Configuration Item
SCIST	Software Configuration Item Summary Table
SCM	Specification Compliance Matrix
SCMP	Software Configuration Management Plan
SDD	Software Design Description
SDS	Safety Data Sheet
SFD	System Functional Description
SFRS	System Functional Requirements Specification
SFTP	Secure File Transfer Protocol
SHA	Safety Hazards Analysis
SHA1	Secure Hash Algorithm 1
SHGC	Solar Heat Gain Coefficient
SI	International System of Measurement
SIC	Standard Industrial Code, U.S. Department of Labor

SNMP	Simple Network Management Protocol
SNTP	Simple Network Time Protocol
SoC	State of Charge
SPB	Shortest Path Bridging
SPLD	Simple Programmable Logic Device
SPMP	Software Project Management Plan
SQA	Software Quality Assurance
SQAP	Software Quality Assurance Plan
SRAM	System Requirements Allocation Matrix
SRS	Software Requirements Specifications
SRTM	Software Requirements Traceability Matrix
SSD	Solid State Drive
SSP	System Safety Program
STP	Software Test Plan
STPr	Software Test Procedure
STR	Software Test Report
SUM	Software User Manual
SVD	Software Version Description
SVPU	Shop Vehicle-Power Unit
SVVP	Software Verification and Validation Plan
SVVR	Software Verification and Validation Report
TCP/IP	Transmission Control Protocol/Internet Protocol
TCN	Train Communication Network
TDB	To Be Determined
TRDP	Train Real Time Data Protocol
TIG	Tungsten Inert Gas
TIR	Total Indicated Runout
TOD	Train Operator Display
TOR	Top of Rail
TVM	Ticket Vending Machine

TWC	Train to Wayside Communication
UDP	User Datagram Protocol
UL	Underwriters Laboratories, Inc.
USASI	United States of America Standards Institute
USDOT	United States Department of Transportation
USP	Universal Service Port
UTC	Coordinated Universal Time
UV	Ultraviolet (light)
VCU	Vehicle Control Unit
VLAN	Virtual Local Area Network
VNC	Vehicle Network Controller
VoIP	Voice over Internet Protocol
VPI	Vacuum Pressure Impregnation
VSWR	Voltage Standing Wave Ratio
V&V	Verification and Validation
WAAS	Wide Area Augmentation System
WB	Wet Bulb
WCN	Wayside Communication Network
WDR	Wide Dynamic Range
WEP	Wired Equivalent Privacy
WiMAX	Worldwide Interoperability for Microwave Access
WMDS	Wayside Monitoring and Diagnostic System
WPS	Welding Procedure Specifications

1.12 Units of Measure

A	ampere
A/V	ampere per volt
Btu/h	British thermal units per hour
Btu/hr/ft^2	British thermal units per hour per square foot
C	degrees Celsius

cd	candela
cm	centimeter
cpm	cycles per minute
dB	decibel
dBA	decibel on the 'A' weighted scale
F	degrees Fahrenheit
fc	footcandle
fps	frames per second
ft	foot
ft^3	cubic foot
ft-lbf	foot pounds force
ft/min	feet per minute
ft^3/min	cubic feet per minute
g	acceleration due to gravity (9.81 m/s^2)
g	gram
gpm	gallons per minute
h	hour
in	inch
in/s	inch per second
Hz	hertz
J	joule
K	kelvin
kg	kilogram
kgf	kilogram force
kHz	kilohertz
km	kilometer
km/h	kilometers per hour
kN	kilonewton
kPa	kilopascal
kWh	kilowatt-hour

l	liter
lb	pound
lbf	pound force
lb/in	pound per inch
l/s	liter per second
m	meter
m^3	cubic meter
mg	milligram
MHz	megahertz
mi	mile
min	minute
ml	milliliter
mm	millimeter
mm/s	millimeters per second
MN/m	meganewton per meter
MPa	megapascal
mph	miles per hour
mph/s	miles per hour per second
mph/s^2	miles per hour per second squared
ms	millisecond
m/s	meters per second
m/s^2	meter per second squared
m/s^3	meter per second cubed
mT	millitesla
µsec	microsecond
mV	millivolt
µV	microvolt
N	newton
N-m	newton-meter
oz	ounce

Pa	pascal
ppm	parts per million
psi	pounds force per square inch
s	second
V	volt
Vac	volt alternating current
Vdc	volt direct current
W	watt
Wh	watt hour
Wh/m²	watt hour per square meter
W/m²	watts per square meter

1.13 Contract Deliverables Requirements List (CDRL)

No CDRLs are required for this Section.

1.14 Referenced Standards

The following standards are referenced in this Section:

36 CFR 1191	Americans With Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities; Architectural Barriers Act (ABA) Accessibility Guidelines, Appendix D, Technical
49 CFR 37	Transportation Services for Individuals with Disabilities (ADA)
49 CFR 38	Americans With Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles

END OF SECTION

Table of Contents

Table of Tables

2.1 General

2.1.1 Scope

This Section describes the operating environment in which the vehicle must perform and establishes general design criteria and system performance.

Related and other requirements may appear in other sections of the Specifications.

PARAMETERS	NEW SEPTA STREETCAR
Usage	SEPTA Subway-Surface Trolley Lines (City & Suburban Divisions)
Length	24.4 meters +/- 1.8 m (80 feet +/- 6 feet)
Width	2641.6 mm (104 inches)
Height	3.700 m or 3,700 mm (12 ft. 1.7 in or 145.7 in)
Track gauge	1,581 mm (5 ft 2+1⁄4 in)
Switches	AREMA-style tongue and mate, all frogs & switches are flange bearing
Maximum grade	7%
Minimum curve radius	10.845 m (35 ft-7 in)
Multi-vehicle trains	No
Maximum speed	70 km/h (43.5 mph)
Voltage	The Substation full Load (Nominal) Voltage is 630 Vdc. (Each trolley feeder breaker is currently rated at 2000 amps.)
Electrical pickup	Pantograph
Direction	Bidirectional
Number of doors	Minimum 2-4 plug doors per side (in the low floor section: see Sections 2.3.3.3 and 2.4.5 for widths)
Seats/Standees	44 minimum (including flip up-seats; 100-120 standees at AW2, 121-139 standees at AW3, 140-160 standees at AW4)
Exterior Colors	TBD
Fleet Size	130 (base order)

2.1.2 Service Proven Design

Base the vehicle and its systems on “service proven” designs, as defined in Section 1, General Topics and Definitions.

1. Derivations from, or extensions of proven designs will be permitted solely at the discretion of the Engineer.
2. The Engineer will assess changes to service proven designs according to, among other factors, the risks to the success of the Project.

2.1.3 Service Life

Base service life on the vehicle operating environment, subject to the maintenance intervals specified in this Section and the Contractor's recommended maintenance practices and normal industry accepted operating procedures.

Comply with the following service life requirements:

1. Vehicles: Minimum 30 years. Annual average mileage is estimated to be 52,300 km (32,505 mi) per vehicle.

2. Vehicle body, truck, and drive train structures: Minimum 30 years without the need for structural repairs.

2.2 Operating Environment

2.2.1 General

The vehicle shall perform as specified in the SEPTA operating environment, as described in this Section.

1. The vehicle will operate on an existing alignment that will be shared with existing vehicles.

2. The vehicle shall be functionally compatible with the existing signal systems and systems defined in TS 21, Communications Based Train Control, and structurally compatible with the existing vehicles.

2.2.2 Climatic Conditions

2.2.2.1 General

Consult official data sources for current versions of these and other relevant data.

1. Actual temperatures and conditions local to the vehicle along the alignment, including those within, underneath, and above the vehicle, may be much more severe than the climatic operating requirements below.

2. The vehicle shall accommodate the environmental extremes on the alignment.

2.2.2.2 Climatic Operating Requirements

The vehicle shall be capable of operating at the specified performance levels and being stored and maintained without impairment resulting from environmental conditions in the Project region. Following are the climatic operating requirements:

1. Ambient air temperature extremes:

    a. Low: -23.5 C (-10 F)

    b. High: 45 C (113 F)

2. Precipitation:

    a. Maximum rainfall rate in 24 hours: 203 mm (8 in)

    b. Maximum snowfall in 24 hours: 610 mm (24 in)

    c. Icing conditions: Vehicles shall be capable of operating under freezing rain and ice conditions without damage to equipment or reduction of useful service life.

3. Relative Humidity:
    a. Minimum: 20%
    b. Maximum: 100%
4. Wind Speed:
    a. Maximum sustained: 60 km/h (37.3 mph)
    b. Maximum gusting: 118 km/h (73.3 mph)
5. Solar Radiation:
    a. Direct normal irradiance: 776 W/m^2 (246 $Btu/hr/ft^2$)
    b. Diffuse horizontal irradiance: 164 W/m^2 (52 $Btu/hr/ft^2$)

2.2.3 Vehicle Wash

Vehicle wash spray:

1. Nozzles per vehicle side: **17 inches (432 mm) spacing per vehicle side**
2. Water volume and pressure: **2.93 l/m (0.776 gpm) at 1.627 MPa (236 psi)**
3. Nozzle distance from vertical surface: **.91 m (3 ft)**

2.2.4 Fordability

The vehicle shall operate without impairment or damage in brackish standing water of depths up to 75 mm (3 in) above TOR at speeds of up to 16 km/h (10 mph).

2.2.5 Alignment

2.2.5.1 Description

The vehicles will operate on the SEPTA alignment in streets in mixed traffic with traffic congestion, traffic lights, bicycles, and pedestrians and on dedicated right-of-way.

1. City Division alignment: Approximately 40 miles of street trackage.
2. Suburban Division alignment: Approximately 12 miles of street trackage.
3. Vehicle speeds: See the Speed Requirements section, below.
4. Track Structure:
    a. At Grade Trackage: 115 RE rail on wood ties and stone ballast.
    b. Street Trackage: 115 RE rail with flangeways formed in concrete. A single restraining rail is used on curves with a radius of 750 feet or less.

c. Turnouts: The City Division makes extensive use of tongue-and-mate turnouts throughout the network. The Suburban Division primarily employs conventional split switch technology, with the exception of a tongue-and-mate turnout located in a critical portion of the 69th Street Terminal loop.

d. Turnout and Crossing Frogs: On the City Division, all frog and mate switches are flange bearing. On the Suburban Division, all frogs are non-flange bearing, or level point design. Note that the at-grade crossing with the CSX RR located at Darby, PA employ OWLS (One-Way Low-Speed) technology on the SEPTA routes through the crossing frogs.

5. Alignment plan and profile: See Appendix [B], Alignment, for example of track chart data to be provided at Notice to Proceed.

2.2.5.2 Track and Route Geometry

TABLE 2-1, TRACK AND ROUTE GEOMETRY		
Parameter	**City Division ***	**Suburban Division * ***
Maximum sustained gradient	7% for 1000 ft, or the worst case on alignment drawings, whichever is greater	7% for 1000 ft, or the worst case on alignment drawings, whichever is greater
Minimum horizontal curve centerline radius	10.845 m (35 ft-7 in)	18.288 m (60 ft-0 in)
Compound curves	To be provided at Notice to Proceed	See Appendix B
Reverse horizontal curves	To be provided at Notice to Proceed	See Appendix B, Alignment
Minimum vertical curve radius, crest	94.48 m (310 ft-0 in) [per 1978 spec.]	300 m (984 ft-3 in) [per 1978 spec.]
Minimum vertical curve radius, sag	140.21 m (460 ft-1 in) [per 1978 spec.]	300 m (984 ft-3 in) [per 1978 spec.]
Reverse vertical curves	To be provided at Notice to Proceed	See Appendix B

*** City Division consists of Routes 10, 11, 13, 15, 34, & 36.**
**** Suburban Division consists of Routes 101 & 102.**

2.2.6 Station Platform Interface

Communicate and cooperate with SEPTA's Buildings and Bridges department regarding platform interface issues to ensure that the wayside/vehicle system complies with ADA requirements and accommodates the vehicle dynamic envelope.

Comply with the following requirements for interface with station platforms:

1. For station platform interfaces, the assumed lateral motion of vehicle from track centerline is +/- 19 mm (0.75 in) at the low floor section, on tangent track with average wheel/rail wear

conditions and normal lateral truck suspension deflections. Adjust designs as necessary if other motions are assumed, as **approved** by SEPTA.

2. Platform Length: Approximately 30.5 m (100 ft). The vehicle shall not overhang the ends of the platform when the vehicle is centered longitudinally on the platform.

3. **Platform Loading Zone Length:** Approximately **30.5 m (100 ft).** The vehicle doorway location and arrangement shall allow for loading and unloading of passengers on the platform within the platform loading zone.

   a. Platform Edges: At a horizontal distance of **1.4m (4 ft. 8in)** from track centerline.Horizontal gap: In the low floor section, design for a gap of 44.5 mm, +/- 3 mm (1.75 in, +/- 0.125 in) between the door threshold edge and platform edge, with the vehicle centered on the track. The tolerance applies to the vehicle only, independent of external tolerances.

   b. Vertical Height: Floor surface height at the low floor section doorways shall be maintained at the height specified in Table 2-3, Vehicle Dimensions, at all passenger loads from AW0 to AW4.

   c. Vehicle Width Including Door Thresholds: Coordinate threshold extensions, if used, with platform dimensions.

   d. **Platform Height: 254 mm** + 0/- 6 mm (**10 in** +0/- 0.25 in) above top of rail.

   e. Platform Width: 2,590.8 mm (8 ft. 6 in)

2.2.7 Radio Frequencies

Perform a radio interference study to confirm the following:

1. That the vehicle shall not interfere with any radio signals present either in the environment or SEPTA's infrastructure and that these signals shall not interfere with onboard equipment.

2. That no radio frequencies used by SEPTA shall be negatively affected by the vehicle.

3. To confirm proper RF operation for the following wireless communications subsystems to be used onboard the vehicle:

   a. WCN

   b. CBTC (Both wireless backhaul and transponder)

   c. TWC

   d. GPS/GNSS

   e. Voice radio

   f. Public Address inductive loops

4. To confirm antenna separation rules for all on-vehicle antennas to avoid inductive coupling.

2.3 Vehicle Description

2.3.1 Vehicle Type and Characteristics

The vehicle shall be an articulated, modern Streetcar with contemporary styling. The vehicle shall have the following characteristics:

1. Body sections (modules): **Minimum three (3),** each separated by an articulated joint.

2. Low floor:

    a. Partial low floor vehicles:

        - Design vehicle with minimum **70% low floor**, measured by the longitudinal length of the low floor section divided by the distance between cab walls.
        - Low floor shall span the distance between high floor sections over the two end trucks and be continuous longitudinally without change in floor level.

    b. **100% low floor** vehicles: Low floor section shall extend from cab wall to cab wall and be continuous longitudinally without change in floor level.

3. Transition from low floor to high floor: Via steps, or via ramps with ramp angle 6 degrees or less.

4. **Bi-directional:** Provide a fully functional cab at each end with operating control and performance equal from both cabs.

5. Heated and air conditioned: Consistent with the Project environment and the Specifications.

6. Powered trucks: **At least two-thirds of the trucks shall be powered**. Provide motoring, dynamic braking, and spin protection for all wheels of powered trucks. See Section 10, Propulsion System and Control, for related requirements.

7. All trucks: Provide friction disc braking and slide protection for all wheels of all trucks. Provide track braking on all trucks. See Section 12, Friction Brake System, for related requirements.

2.3.2 Vehicle Configuration Requirements

2.3.2.1 Doorway Quantity and Locations

Comply with the following:

1. Quantity of doors: **Two to four plug doors per side in the low floor section**.

2. Total doorway span:

    a. Partial low-floor vehicles: Maximum total doorway span for doors in the low-floor section shall be the length of the shortest platform loading zone, as specified above, minus 600 mm (2 ft), to preclude low-floor doors from opening off-platform.

    b. 100% low-floor vehicles: Maximum total doorway span shall not exceed the length of the shortest platform loading zone, as specified above, minus 600 mm (2 ft), to preclude low-floor doors from opening off-platform.

2.3.2.2 Seating

Provide minimum **44** passenger seats, including flip-up seats.

See Section 14, Interior and Exterior Appointments, for seat requirements, including dimensions.

2.3.2.3 Standing Space

Provide standing space for minimum 100 passengers at AW2 loading density.

2.3.2.4 Bicycle Racks

Provide bicycle stowing racks:

1. Location: Both sides of the vehicle.
2. Capacity: Four bicycles.
3. Rack requirements: See Section 14, Interior and Exterior Appointments.

2.3.3 Mobility Impaired Accommodations

2.3.3.1 General

Mobility impaired accommodations shall comply with 49 CFR 38, Subpart D.

2.3.3.2 Accessible On-Board Circulation Path (AOCP)

The AOCP connects accessible features on the vehicle, including accessible doorways and mobility aid parking areas:

1. AOCP Clear Width: Minimum **32 inches.**
2. Bridge Plates: Provide at a minimum, two, one on each side of the vehicle, at double-leaf doorways in the low floor section. The location of bridge plates shall be **approved** by the engineer.
3. AOCP Route: Between each bridge plate doorway and the specified mobility aid parking areas.
4. Signage: If not all doors give access to an AOCP route, provide the international symbol of accessibility on vehicle interior and exterior at each AOCP doorway. See Section 14, interior and Exterior Appointments, for additional signage requirements.

2.3.3.3 Vehicle Entryway Width

Comply with the following:

1. Doorway Entrance:
   a. Single Leaf Doorway: Entry width of no less than **32 inches**
   b. Double Leaf Doorway: Entry width between **48 inches and 58 inches**
2. Vestibule: Vehicles where windscreens, modesty panels, or other partitions establish an entrance or "vestibule" area separate from the occupied passenger space:
   a. Vestibule width: Minimum **44 inches** over the most restrictive protrusion, where 90 degree or similar turns are required immediately upon entering the vehicle
   b. Exception: If the vestibule is arranged to allow a free-flowing path into the passenger area or aisle leading to that area, then the most restrictive width of the vestibule near the door may be less than **44 inches**, but in no case can the accessible on-board circulation path be less than **32 inches**
3. No Vestibule: Vehicles that do not have physically defined separation between entrance areas and passenger occupied areas but require 90 degree or similar turn on to the Accessible On-board Circulation Path:
   a. Clear path dimension: Minimum **44 inches** wide across the vehicle free from panels or stanchions
   b. Path configuration: Should be a straight line across the doorways on opposite sides of the vehicle
   c. Exception: Entrances that are not on the Accessible On-Board Circulation Path or do not lead to a mobility aid parking area are not bound by this requirement

2.3.3.4 Mobility Aid Parking Areas

Provide mobility aid parking areas in each vehicle according to door configuration:

1. **Two double-wide doors** on each side: Minimum two mobility aid parking areas, adjacent to the double-wide doorways with bridge plates.
2. **Three double-wide doors** on each side: Minimum two mobility aid parking areas and one area with flip-up seats to allow space for mobility aid parking, each adjacent to a double-wide doorway with bridge plate.
3. **Four double-wide doors** on each side: Minimum two mobility aid parking areas and two areas with flip-up seats to allow space for mobility aid parking, each adjacent to a double-wide doorway with bridge plate.

Provide, at a minimum, two mobility aid parking areas in each vehicle. The location of mobility aid parking areas shall be **approved**.

See Section 14, Interior and Exterior Appointments, for mobility aid parking area requirements.

2.4 Vehicle Weights and Dimensions

2.4.1 General

Weights and dimensions shall be as indicated below. Construction tolerances of dimensions shall be as stated on the Contractor's drawings unless specifically stated in the Specifications.

2.4.2 Weights

Vehicle weight is based on a streetcar that is complete in all respects with all equipment, materials, and fluids required for operation. The following weight restrictions are based on a streetcar having three trucks with centers spaced 8,400 to 9,200mm apart, each with two axles spaced 1,800 to 1,900mm apart. Total vehicle weight may not exceed 101,500 pounds at AW0. Center truck weight at AW0 may not exceed 31,700 pounds and the end trucks at AW0 may not exceed 37,300 pounds each. Development of any Streetcar outside of those ranges must be coordinated with SEPTA's Bridges & Buildings department for **approval**.

The weight of each vehicle, including passengers at 70 kg (154 lb) each and wheelchair passengers at 272 kg (600 lb) each, shall be defined as follows:

TABLE 2-2, VEHICLE WEIGHT DEFINITIONS	
AW0	Empty vehicle operating weight
AW1	Full seated load (passengers plus Operator), plus AW0
AW2	Standees at four persons per m^2 of suitable standing space per passenger, plus AW1
AW3	Standees at six persons per m^2 of suitable standing space per passenger, plus AW1
AW4	Standees at eight persons per m^2 of suitable standing space per passenger, plus AW1

Notes to Table:

1. Suitable standing space shall include areas of the aisles where it is possible for passengers to stand.
2. The ratings of vehicle equipment and systems shall be based on the actual weight and passenger capacity of the vehicle.

2.4.3 Weight Balance

Arrange equipment so that its weight is distributed to maximize adhesion and minimize the tendency to derail. Each vehicle shall meet the following balancing requirements when complete with all necessary apparatus and for all specified passenger loading conditions:

1. A-end and B-end trucks: The difference in vehicle weight supported by each truck at the rail shall not exceed 900 kg (1984 lb) for all loading conditions from AW0 to AW4.

2. Center truck (if provided): The vehicle weight supported at the rail shall be within the range of 25% to 40% of the total vehicle weight for all loading conditions from AW0 to AW4.

3. Lateral imbalance: At AW0 load, the difference in weight supported by each rail at each truck shall not be greater than 340 kg (750 lb).

2.4.4 Vehicle Dimensions

TABLE 2-3, VEHICLE DIMENSIONS	
Vehicle length: Allowed range, measured over the longest extent of vehicle equipment with couplers stowed	**24.4 m +/- 1.8 m (80 feet +/- 6 feet)**
Nominal vehicle body width (without thresholds):[1, 2]	**2650 mm (104 in)**
Vehicle body width at low-floor doorways (without thresholds):	Same as approved nominal vehicle body width +/- 3 mm (+/- 0.125 in)
Vehicle width over thresholds at low-floor doorways:	As necessary to meet requirements in Station Platform Interface section
Height of roof equipment: Maximum (excluding pantograph) above TOR with new wheels at AW0, including roof shrouds	**3,700 mm (145.7 in)** [3]
Coupler height: Nominal, vertical centerline above TOR with new wheels at AW0	470 mm (18.5 in)
Anticlimber height:	As necessary to meet the anticlimber requirements of Section 3
Low floor height above TOR at AW0:	356 mm, +/- 9 mm (14 in, +/- 0.375 in) or ADA compliant with all platform heights as **approved**
Interior ceiling height: Minimum, including anything mounted on the ceiling in normal walking and standing areas	2030 mm (80 in)
Cab Interior ceiling height: Minimum	1980 mm (78 in)

Notes to Table:

1. Nominal width of the vehicle body, including the entire length of the vehicle (except the cab areas), from low-floor level up to the level of the lower edge of the passenger windows in either the low-floor or high floor section, whichever is higher. The width may be tapered above that level. This width is exclusive of load leveling, bridge plates, and thresholds.

2. Tolerance for vehicle body width at floor level at all doorways (without thresholds): +/- 3 mm (1/8 inch).

3. At no time shall roof equipment interfere with catenary or overhead structures.

2.4.5 Doorway and Door Dimensions

TABLE 2-4, DOORWAY AND DOOR DIMENSIONS	
Minimum side doorway clear opening width:	
Single Leaf Plug Door:	**813 mm (32 in)**
Double-leaf Plug door:	**1220 mm (48 in) to 1473 mm (58 in)**
Minimum side doorway clear opening height:	**1955 mm (77 in)**

2.4.6 Pantograph Dimensions

The pantograph location on the vehicle body, combined with pantograph head and carbon dimensions, shall produce optimum operation and current collection under all conditions on the Project alignment.

TABLE 2-5, PANTOGRAPH DIMENSIONS		
Maximum height above TOR in the lockdown position, new wheels, vehicle at AW0 passenger weight:	3600 mm (141.7 in)	
Pantograph shall operate on contact wire within this height range, vehicle weight from AW0 to AW4, and with new to fully worn wheels	City Division	3734 to 6706 mm (12 ft-3 in to 22 ft)
	Suburban Division	4115 to 5486 mm (13 ft-6 in to 17 ft-11 in)
Maximum collector width over horns:	1194 mm (47 in)	
Minimum carbon shoe length:	279 mm (11 in)	
Carbon spacing:	305 mm (12 in)	
Carbon lateral radius on primary wear area	0 mm (flat)	
Maximum lateral displacement of centerline of pantograph shoe at any operating height due to pantograph sway:	+/- 50 mm (2 in)	
Two-Truck Design - Maximum longitudinal distance from truck centerline to center of pantograph shoe, locked down: Three-Truck Design - Maximum longitudinal distance from center-truck centerline to center of pantograph shoe, locked down:	1275 mm (50 in)	

2.4.7 Vehicle Clearance

2.4.7.1 On the Project Alignment

Vehicles shall operate in the Project environment without physical interference with equipment and structures along the wayside. Dimensions shall not exceed those shown for Dynamic Envelope and Curve Offsets in Appendix A, under the worst-case combinations of the following:

1. Construction tolerances.
2. Wheel and rail wear.
3. Maximum possible body roll.
4. Suspension motions and failures.
5. All other variables within the Contractor's control.

2.4.7.2 At Platform

Design the lower door edge such that the door will always open under failed suspension conditions and worst-case platform clearances, but not contact the platform within the leveling range.

2.4.7.3 In the Shop

Verify clearance dimensions between existing overhead shop walkways at the level of vehicle roof.

2.4.7.4 Under-Vehicle

Vertical under-vehicle clearance is defined from top-of-rail with the maximum suspension deflection and vehicle body roll, minimum vertical curve radius, maximum track superelevation, and fully worn wheels.

1. Vertical clearance:
    a. Under floor: Minimum 90 mm (3.6 in)
    b. Under truck: Minimum 50 mm (2 in)
    c. Vertical clearances exclude track brakes, safety bars, and sanding nozzles.
2. Clearances between truck components and vehicle body: As specified in Section 11, Truck Assemblies.

2.4.8 Wheel Dimensions

TABLE 2-6, WHEEL DIMENSIONS	
Nominal Diameter, new:	610 mm to 711 mm (24 in to 28 in)
Wear on diameter, at condemning limit:	No less than 50 mm (2 in)
Wheel Profile:	Per Wheel-to-Rail Interface Study. See Appendix C
Back-to-Back Dimension:	Per Wheel-to-Rail Interface Study. See Appendix C

2.5 Wheel-to-Rail Interface

2.5.1 General

The vehicle truck design and wheels shall be compatible with the chosen rail sections and track design. The combined design of the truck, wheels, and rail shall optimize the wheel-to-rail interface for the following:

1. Minimum wheel and rail wear.
2. Minimum propensity to derail.
3. Wheel/rail noise reduction.
4. Ride quality enhancement.

2.5.2 Wheel-to-Rail Interface Study (WRIS)

Before starting the WRIS, submit a plan and schedule. Upon receipt of Approval, conduct the WRIS:

1. Ensure that the wheel-to-rail interface has been optimized as specified.
2. Confirm compliance with the wheel equalization requirements specified in Section 11, Truck Assemblies.
3. Coordinate among the various parties to the wheel-to-rail interface in the conduct of the study.
4. After completion of the study, submit a report. Upon Approval of the report, implement the results of the WRIS on the vehicle elements.
5. The recommendations of the study shall become part of the Contract Documents and the vehicle design requirements.

2.6 Supply Voltages

2.6.1 Primary Line Voltage

2.6.1.1 General

Vehicle equipment operated directly from the primary input source shall not suffer damage or reduction of required service life under any continuous primary input voltage from zero up to, and including, the maximum values defined below.

2.6.1.2 Traction Power Substation Supply

The vehicle primary input power will be from an OCS supplied by dc substations:

1. Substation voltage: **630** Vdc at 100% rated load.
2. Substation regulation: 6%.
3. Rectification:
    a. Mainline: 12-pulse
    b. Yard: 12-pulse
    c. Shop: 12-pulse

2.6.1.3 Vehicle Line Voltage

For performance requirements, nominal vehicle line voltage is defined as **630** Vdc, regardless of substation design voltage.

2.6.1.4 Line-Voltage Range

Comply with the following:

1. Equipment operating directly from OCS line voltage:
    a. Shall not suffer damage or reduction of required service life under any continuous line voltage from zero up to, and including, the highest non-permanent voltage value as defined in IEC 60850 for the **630** Vdc nominal category.
    b. Shall shut down or disconnect from the source if necessary to protect against damage for line voltages outside the range between **325** Vdc and the highest permanent value defined in IEC 60850 for the **750** Vdc category. Equipment shall automatically restore operation upon removal of the condition.
2. Existing alignment:
    a. Adjust control parameters via software to not exceed the voltage or current limitations of the existing infrastructure and vehicles. See Section 10, Propulsion System and Control, for maximum braking voltage limitation.

b. These parameters shall be resettable to IEC 60850 compliant values at any time by SEPTA.

2.6.1.5 Performance Upon Loss of Primary Power

Loss of primary power shall not cause an abrupt change in vehicle performance:

1. In power mode: Change to coast or a minimum brake.
2. In brake mode: Remain in same brake mode at same brake rate.
3. Other systems: Shut down in a controlled manner, without spurious behavior or damage.

2.6.2 Auxiliary Power System

See Section 9, Electrical Equipment, for auxiliary ac inverter and dc low-voltage power supply voltages.

2.6.3 Regenerative Braking Voltage

See Section 10, Propulsion System and Control, for maximum permissible regenerative braking OCS voltage.

2.6.4 Line Current Limit

Limit maximum line current, including all OCS-connected vehicle loads, to 750 A. A higher maximum line current limit may be submitted for **approval** in conjunction with SEPTA's Power Department.

2.6.5 Transients and Abnormal Electrical Conditions

Design shall protect equipment on the vehicle from the following:

1. Damage or continued shutdown caused by random interruptions of the OCS power due to isolation gaps, pantograph bounce, or other conditions.
2. Transients and voltage surges typical of rail transit, and as specified in IEC 60850 for line voltage-connected equipment, and IEC 61287 for all other equipment.

2.7 Performance Requirements

2.7.1 General

Specified performance shall be independent of wheel wear, climatic conditions, and vehicle weights, unless otherwise indicated in the Contract Documents.

2.7.2 Load Leveling

Under normal conditions, the load leveling system shall keep the vehicle floor and door threshold height above top-of-rail to the value and tolerance specified in this Section. See also Section 11, Truck Assemblies.

1. The load leveling system shall make floor height adjustments as long as dc low-voltage power is available.

2. System controls and response shall behave as follows:

    a. Vehicle speeds above no-motion: System makes no height adjustments, avoiding corrections due to normal vehicle motions.

    b. No-motion: System makes height adjustments dynamically, including during passenger load changes, maintaining constant floor height.

    c. Ensure that floor height is at required value before a Door Open command can be issued.

    d. In the event of a system failure, the load leveling system shall revert to a safe operating mode to be **approved** by SEPTA.

2.7.3 Load Compensation

Provide an independent passenger load measuring system for each truck:

1. Propulsion and braking efforts shall be apportioned among the trucks according to passenger load distribution, to meet specified performance requirements.

2. Appropriately conditioned signals shall be sent to the propulsion and braking systems for load compensation to meet specified performance requirements.

3. This system shall be active at stand still and with open doors only. Load values shall be memorized once the doors are closed and the vehicle starts moving.

4. Sensors and associated circuits shall be continuously or periodically checked to verify that they are functioning properly.

5. If independent control logic units are provided as part of load compensation, they shall comply with Section 17, Controls, Networks, and MDS.

See also Section 10, Propulsion System and Control, Section 11, Truck Assemblies, and Section 12, Friction Brake System.

2.7.4 Communications-Based Train Control (CBTC)

Coordinate design of the following systems specified in this Section with CBTC, specified in Section 21, Communications Based Train Control:

1. Overspeed protection.

2. Braking requirements:

    a. Provide full service brake (FSB) application in response to penalty brake command.

    b. Maintain irreversible FSB application until zero speed is achieved.

    c. Report blended braking performance feedback to CBTC.

3. Wheel spin/slide detection and correction.

4. Propulsion requirements:

a. Inhibit propulsion when braking is commanded.

2.7.5 Speed Requirements

When operating from the OCS, the vehicle and its equipment shall be designed to operate at the following speeds, as defined in Section 1, General Topics and Definitions:

1. Vehicle design speed: **70 km/h (43.5 mph)**
2. Propulsion and braking design speed: Minimum **95 km/h (59 mph)**.
3. Maximum operating speed:
   a. **70 km/h (43.5 mph),** irrespective of civil speed limits on the existing alignment.
   b. The maximum operating speed may be automatically limited by the vehicle under certain specified conditions.

See Section 10, Propulsion System and Control, for overspeed protection; Section 13, Vehicle Communication Systems; and Section 21 Communications Based Train Control.

2.7.6 Propulsion and Braking Design Criteria

Propulsion and braking equipment shall interface to produce the specified performance values. The basis for performance calculations, designs, and evaluation shall be as follows:

1. Acceleration, braking and jerk rates shall be based on level tangent dry track in still air except when otherwise noted in the Contract Documents.
2. Initial acceleration rates shall be as required by this Section over a 400 Vdc to 925 Vdc range at the OCS.
3. Braking rates shall be independent of the OCS voltage:
   a. Performance in dynamic braking shall be available at all line voltages down to, and including, 0 V, assuming line voltage is present at initiation of braking.
   b. Performance in friction braking modes shall be available at all line voltages down to, and including, 0 V.
   c. Friction braking shall automatically supplement dynamic braking, on a per-truck basis, whenever dynamic braking is not providing the requested braking effort.
4. Performance capabilities shall be achieved over the specified full range of the following:
   a. Wheel wear
   b. Ambient temperatures
   c. Low-voltage power supply voltage

2.7.7 Not Used

2.7.8 Acceleration Requirements

When operating from the OCS at nominal line voltage and higher, the vehicle shall achieve the instantaneous acceleration rate below with the Master Controller (MC) at maximum power position at all vehicle weights from AW0 to AW2.

1. Average acceleration between 0 and 32 km/h (20 mph): 1.34 m/s^2, with no variation in the instantaneous rate greater than +/- 5% of the average.

2. Time to reach 40 km/h (25 mph) from 0 km/h: Less than 10 seconds.

3. Time to reach 70 km/h (43 mph) from 0 km/h: Less than 25 seconds.

Reduced performance requirements:

1. Weights greater than AW2: Acceleration rate may be reduced in direct proportion to the ratio of AW2 weight/actual vehicle weight.

2. OCS line voltages between nominal and 525 Vdc, weight AW2 or less: Vehicle shall achieve the specified acceleration rate. However, the speed to which the acceleration is maintained may be reduced in direct proportion to line voltage/nominal voltage.

3. OCS line voltages between 525 and 400 Vdc, weight AW2 or less: Vehicle shall achieve the specified acceleration rate. However, provide further reduction in the speed to which the acceleration is maintained, via an automatic current limiting scheme:

    a. Current limiting parameters: Adjustable

    b. Initial setting: 5 A/V, where “V” is the difference between 525 V and actual line voltage

    c. Final setting: Optimize this value during commissioning and finalize this value during the warranty period

2.7.9 Braking Requirements

2.7.9.1 General

Vehicle braking shall be performed by dynamic braking, friction disk braking, and track brakes. Adhesion may be augmented by the application of sand, as specified.

The instantaneous and average brake rates shall be as indicated below for vehicle weights from AW0 to AW3. Above AW3, brake efforts may be fixed at no less than the AW3 levels.

Vehicle braking distance requirements shall conform to results of safe braking analysis, as **approved** by SEPTA.

2.7.9.2 Non-Powered Truck Braking

Comply with the following if a non-powered truck is provided:

1. Normal braking conditions: Minimize friction braking effort for the non-powered truck to maximize use of dynamic brake.

2. Slide controlled or emergency braking: Each wheel/axle shall be braked to ensure an equal distribution of adhesion levels for each wheel/axle, subject to review and Approval.

3. Dynamic brake failure conditions: Friction braking effort among the wheels/axles may be redistributed, subject to review and Approval.

2.7.9.3 Service Brake

Comply with the following:

1. Composition: Service brake (SB) shall use dynamic and friction disk braking. At all vehicle weights, SB shall be 100% dynamic braking down to the dynamic brake fade point (see Section 10, Propulsion System and Control).

2. Braking rate: At FSB position on the MC, SB shall produce the following average braking rates from any entry speed to zero. Throughout the stop, the instantaneous rate shall not vary outside the specified average brake rate tolerance indicated:

    a. All dynamic brakes functional: 1.34 m/s^2 (4.40 ft/s^2), +/- 5% (above low-speed fade point)

    b. One dynamic brake unit inoperative: 1.34 m/s^2 (4.40 ft/s^2), +/- 10%

    c. Transition between dynamic and friction brakes (fade point): 1.34 m/s^2 (4.40 ft/s^2), +/- 20%

    d. 100% friction braking: 1.34 m/s^2 (4.40 ft/s^2), +/- 20%

2.7.9.4 Maximum Brake

Comply with the following:

1. Composition: Maximum brake (MB) shall use dynamic, track brake, and friction brake as necessary to achieve specified performance. MB shall maximize the use of dynamic braking, filling in with friction braking only as necessary. Slide protection shall be active.

2. Braking rate: At MB position on the MC, MB shall produce the following average braking rates from any entry speed to zero, with no +/- variation in the instantaneous rate greater than indicated:

    a. All dynamic brakes functional: 2.25 m/s^2 +10%, -0%

    b. One dynamic brake unit inoperative: 2.25 m/s^2, +15%, -0%

    c. With 100% friction braking: 2.25 m/s^2, +20%, -0%

2.7.9.5 Emergency Brake

Comply with the following:

1. Operator control: Provide an Emergency Brake Switch as specified in Section 5, Operator's Cab Controls.
2. Composition: Emergency braking (EB) shall use a combination of friction disc brakes, track brakes, dynamic brakes, and the application of sand. Friction brake effort shall be independent of dynamic brake effort:
    a. AW1 and below: Minimum EB rate shall use only friction disc brakes, track brakes, and application of sand.
    b. Above AW1: Dynamic brakes may supplement friction disc brakes, track brakes, and application of sand to achieve minimum EB rate.
3. Braking rate: When EB is commanded, EB shall produce the following braking rate from any entry speed to zero:
    a. Instantaneous braking rate: Shall not exceed 3.5 m/s^2
    b. Average braking rate: 2.25 m/s^2, +20%, -0%
4. Function of systems during EB:
    a. Spin-slide system: Cut out during EB
    b. Jerk limiting: Shall not be applied to EB
    c. Other vehicle systems: Shall not inhibit EB
    d. Interlock with vehicle speed:
        - EB command: Irretrievable to the no-motion detection speed
        - Track brake release: At approximately 5 km/h (3 mph), to be fine-tuned during commissioning
        - Sanding termination: At no-motion detection speed
5. EB is a safety system:
    a. Control line: Double-wire double-break as follows:
        - Both positive and negative supply leads to the EB relay shall be switched by the cab console emergency brake switch.
        - Separate positive and negative control wires from the EB relay(s) with duplicate switching contacts for each control function in the positive and negative control lines.
    b. Vital circuits: Treat EB control circuits, including wiring, as vital, with maximum isolation maintained from possible sources of false energization.
    c. Failsafe: Arrange EB circuits in a failsafe manner, such that control lines must be energized to sustain a permissive condition.

2.7.9.6 Dynamic Brake Failure

In the event of dynamic brake failure, comply with the following:

1. Friction disk brakes shall automatically produce the necessary braking efforts to achieve the requested braking rate.

2. After the initial stop with a dynamic brake failure, the system shall automatically reduce vehicle maximum operating speed if vehicle loading is above AW3, as **approved**, as necessary to conform to friction brake thermal limitations.

2.7.9.7 Parking Brake

Provide parking brakes capable of stopping and holding a vehicle as follows:

1. Weight: Up to AW4.

2. Grade: Maximum 7%, or worst case on alignment drawings, whichever is greater.

3. Duration: Indefinitely.

See Section 12, Friction Brake System, for parking brake requirements.

2.7.10 Wheel Spin/Slide Detection and Correction

Provide a wheel spin/slide system complying with the following:

1. Performance:

   a. System shall detect and correct wheel spin and slide on all wheels of the vehicle, both in acceleration and braking.

   b. Spin/slide protection shall be active in all motoring and braking modes.

2. Safety:

   a. Design the system for safe operation such that a spin/slide system failure shall not prevent the application of braking at any level less than desired, in any braking mode.

   b. Include a safety supervision algorithm to override the brake release on a per truck basis if a slide condition is determined to be excessive, subject to Approval.

3. Detection:

   a. The system shall detect both individual and synchronous slides or spins by evaluation of axle or wheel speed differences and axle/wheel acceleration/decelerations.

   b. The system shall use the speed information from all axles of the vehicle.

   c. The system shall detect a locked axle or loss of speed sensor.

   d. The system shall modify the deceleration detection level during track brake applications.

4. Correction:

    a. Spin/slide correction shall use modern methods of tractive effort modulation that are in proportion to the magnitude of the detected spin or slide.

    b. Sanding shall be applied automatically during correction of major spins and slides. Sanding shall be cancelled at no-motion or if the spin/slide condition is corrected.

    c. Removal of effort shall not be jerk limited during spin/slide corrections.

    d. The correction system shall function as specified independent of wheel diameter differences.

5. Efficiency:

    a. Minimum 90% at all adhesion levels down to and including 5%, as measured by an inertial accelerometer on rails with artificially reduced adhesion.

    b. Calculate efficiency as the ratio of actual acceleration to achievable acceleration, using an **approved** calculation method.

    c. Take measurements only during periods of actual spin/slide activity when wheels are spinning or sliding.

6. Related sections: See also Section 10, Propulsion System and Control, Section 12, Friction Brake System, and Section 21, Communications Based Train Control.

2.7.11 System Response Times

Response time for any change in MC position within a power or brake mode: Maximum 150 ms, to the resultant tractive effort change, as measured by dv/dt of axle speed.

2.7.12 Jerk Limits

Comply with the following:

1. Rate of change in acceleration (jerk): Actively controlled at 0.89 to 1.34 m/s^3, or other agreed value.

2. Jerk limiting applies:

    a. To all normal power and service braking applications.

    b. During all requested changes in power and brake efforts within the same mode, when rate of change request is greater than the limit.

3. Jerk limiting does not apply:

    a. During emergency brake or manual track brake applications.

    b. During spin/slide correction.

    c. During power removal due to loss of primary line voltage.

   d. Where rate of change request is less than the jerk limit: The system shall follow the command signal rate of change within specified accuracy limits.

4. Jerk limiting adjustments:

   a. For direct mode change between Power and Brake via MC, jerk limiting of power removal shall be canceled when the MC reaches any brake position.

   b. For overweight vehicles, such as an AW3 vehicle with AW2 effort limit, the effort application rate shall be increased to achieve nominal jerk limit.

2.7.13 Mode Change Dead Times (MCDT)

Comply with the following:

1. MCDT: Less than 300 ms for the following direct mode changes:

   a. Power to Brake, from point of jerk limit cancellation (above)

   b. Coast to Brake

   c. Coast to Power

2. MCDT for Brake to Power:

   a. Braking fully dynamic: 300 ms

   b. Friction brakes involved: 400 ms

   c. If traction motors must be magnetized: Less than 1 second, as **approved**

3. MCDT for EB: 400 ms or less, regardless of original mode.

4. Measurement of MCDT: From the time that the control line(s) change(s) state, until the vehicle has achieved 10% of the requested acceleration or deceleration.

2.7.14 No-Motion Detection System

Provide a no-motion detection system complying with the following:

1. Range: System shall detect vehicle motion down to, and including, 1 km/h (0.6 mph).

2. Safe signal: System shall transmit a signal to indicate no-motion state, for other vehicle systems that require such information.

3. Redundancy: System shall monitor all axles and include at least two independent circuits to generate the no-motion state.

4. Configuration: System shall be on a per vehicle basis and shall not be trainlined.

2.7.15 Speed Sensing

Provide and integrate speed sensing devices for all systems that require speed information, and as specified:

1. Systems may share speed information if buffering and isolation between signals is provided, and only as **approved**.
2. Integrate systems' requirements to minimize the types of sensors.
3. Select sensor types and installation methods such that mechanical adjustments are not required for installation or replacement.
4. Incorporate speed sensors into truck or gearbox designs, as appropriate:
    a. Speed sensors shall not be shared among systems, except as **approved**.
    b. Provide at least one spare sensor port on each truck for each sensor type.
5. Speed sensing devices shall meet the requirements of Section 10, Propulsion System and Control, and Section 21, Communications Based Train Control.

2.7.16 Rollback Prevention

Design the propulsion and braking systems with sufficiently precise controls to prevent the vehicle from rolling in a direction opposite to that selected by the Reverser on any specified grade and at any vehicle loading:

1. Accelerating from a stop:
    a. Design systems to limit vehicle rollback until motor torque is sufficient to hold or move the vehicle.
    b. Maximum rollback distance (AW3 vehicle): 400 mm (16 in).
2. Moving MC from motoring to coast:
    a. Design systems to detect and prevent rollback either by maintaining motor torque to hold the vehicle at zero speed, or by applying friction brakes upon detection of reverse motion.
    b. Maximum rollback distance (AW3 vehicle): 150 mm (6 in).
    c. Maximum speed during rollback (AW3 vehicle): 1.6 km/h (1 mph).

2.7.17 Duty Cycle

The vehicle shall operate on the intended alignment, under worst case ambient conditions, without exceeding the thermal ratings of equipment.

2.7.17.1 Normal Duty

The vehicle shall be capable of operating continuously over the specified alignment, in all directions, at AW2 passenger loading, on the following duty cycle:

1. Full power acceleration to the civil speed for each track segment.
2. Maintaining that speed until brake.
3. Full service deceleration to a stop.
4. Eight-second dwell time at each station.
5. Two-minute layover at each end of the line.

2.7.17.2 Rescue Operation

Comply with the following:

1. An operating vehicle shall have the capacity to tow or push an inoperative vehicle as follows:
   a. Operating vehicle:
      - Full acceleration and braking tractive effort
      - Up to AW3 weight
   b. Inoperative vehicle:
      - Brakes released (not functional)
      - AW3 weight
   c. Operating vehicle performs the following:
      - Tows or pushes inoperative vehicle to the next available unloading location
      - Moves empty inoperative vehicle to Shop via worst-case (most severe duty cycle) routing, at speeds of up to 40 km/h (25 mph)
2. Inoperative dynamic braking on a vehicle or truck:
   a. A maximum operating speed restriction may be imposed, as specified in the Dynamic Brake Failure section, above.
   b. Vehicle shall have the capacity for continuous operation at AW2 load on the alignment without exceeding the continuous rating of any equipment.

2.7.18 System Redundancy and Recovery

Comply with the following:

1. Design the vehicle such that it can continue to operate under failure conditions:
   a. Provide devices and establish procedures to disable the failed system and allow the remaining systems to continue operation.

   b. Performance may be limited, except where specifically indicated otherwise.

2. The following systems shall be physically and functionally redundant and share no components except where specifically permitted:

   a. Propulsion

   b. Friction braking

   c. HVAC

   d. AC and DC power sources (see Section 9, Electrical Equipment, for allowed alternative arrangements)

Specific requirements for each system are specified elsewhere in the Specifications.

2.8 Noise and Vibration Limits

2.8.1 General

Unless otherwise noted in the Contract Documents, the specified noise limits apply to equipment that operates on a regular basis and do not apply to equipment that operates infrequently, such as a circuit breaker or pneumatic pressure relief device. Perform sound measurements as specified in Section 15, Testing.

2.8.2 Pure Tones

The maximum allowable noise levels specified below shall be reduced by at least 3 dB under the following circumstances:

1. Significant pure tones in the range from 250 Hz to 8,000 Hz are present in the noise.

2. Pure tone noise is considered significant in this context if any one-third octave band sound pressure level is 3 dB, or more, higher than the arithmetic average of the two adjacent bands containing no pure tones.

2.8.3 Interior Noise Limits

TABLE 2-7, INTERIOR NOISE LIMITS

Limit	Location	Conditions
68 dBA	Interior	Vehicle stationary, windows and doors closed, air conditioning equipment operating in full cool, and all auxiliary equipment operating simultaneously under normal operating conditions.
65 dBA	Cab, at seated Operator’s ear height	Vehicle stationary, windows and doors closed, and air conditioning equipment operating in cooling mode.
75 dBA	Interior	Vehicle operating on the Project alignment, on smooth rail, at any speed up to 56 km/h (35 mph), and under any acceleration or deceleration condition.

2.8.4 Wayside Noise Limits

TABLE 2-8, WAYSIDE NOISE LIMITS	
Limit	**Conditions**
70 dBA	Vehicle stationary and empty, air conditioning equipment operating in full cool, and all auxiliary equipment operating simultaneously under normal conditions.
75 dBA	Vehicle operating on the Project alignment, on smooth rail, at any speed up to 56 km/h (35 mph), under any acceleration or deceleration condition. The same noise limits apply in any combination of active or disabled dynamic brake and with receptive or non-receptive OCS.

See Section 15, Testing, for detailed noise testing parameters.

2.8.5 Vibration Limits

Comply with the following:

TABLE 2-9, INTERIOR VIBRATION LIMITS	
Frequency	**Vibration Limit**
Below 1.4 Hz	Maximum deflection (peak-to-peak): 2.5 mm (3/32 in)
1.4 Hz to 20 Hz	Peak acceleration: 0.1 m/s^2
Above 20 Hz	Peak velocity: 0.75 mm/s

Vehicle equipment operation shall not cause visible or audible vibrations:

1. Anywhere on the vehicle floor, walls, ceiling panels, or seat frames
2. At any specified operating speed
3. Under any acceleration or braking condition except emergency braking

2.8.6 Effects of Shock and Vibration on Vehicle Equipment

Comply with the following:

1. Equipment shall operate without damage or degradation of performance when subjected to vibration and impacts encountered during normal service.
2. Equipment shall comply with IEC 61373, including functional and durability requirements.
3. Electronic equipment shall comply with EN 50155 and IEEE 1478.

2.9 Ride Quality

Design vehicle with ride quality according to ISO 2631 as applicable to the rail vehicle design:

1. Rms acceleration values: Maximum 0.32 m/s^2 for each measurement point for Operators and passengers, seated or standing.

2. Vibration total value (root sum of squares summation): Maximum 0.5 m/s^2 for each when calculated for each measurement point.

3. Evaluate acceleration data over the range of 0.5 Hz to 80 Hz. Where appropriate, use frequency weighting Wb instead of Wk.

2.10 Electromagnetic Interference (EMI) and Compatibility (EMC)

2.10.1 General

The vehicle, its systems, and its components shall not cause EMI that results in malfunctions of the following:

1. Onboard equipment and systems.

2. Existing vehicles on the Project alignment.

3. Existing and new wayside equipment, including the following:

    a. Signaling system

    b. Train to wayside communications

    c. GPS/AVL system

    d. Traffic signal controllers

    e. Voice radio system

    f. TWC loop controls

Limit vehicle emissions as defined below, and verify by test as specified in Section 15, Testing.

2.10.2 Design and Implementation

Comply with the following:

1. Limit and apportion individual equipment emissions as necessary to limit point-source emissions and to achieve defined vehicle limits.

2. To contain EMI emissions, wherever possible, suppress transients at their source.

3. Employ design techniques, construction methods, and whatever equipment is required to prevent interference caused by internal sources from affecting the proper operation of vehicle and external systems:

   a. Coordinate frequencies, EMI levels, and susceptibility levels.

   b. Provide necessary on-board grounding, balancing, filtering, shielding, modulating techniques, and isolation to meet the requirements of this Section.

   c. Employ electrostatic and magnetic shielding methods to minimize the effect of stray signals and transient voltages on interconnecting cables.

   d. Physically separate power and signal cables.

   e. Locate and arrange trainlines to minimize voltage induction into trainline circuits due to propulsion system, auxiliary power, and OCS current transients.

2.10.3 Individual Subsystems

2.10.3.1 General EMC Compliance

Each individual subsystem containing electronics shall comply with all applicable requirements of EN 50121-3-2 and shall be tested for compliance in an EMC testing laboratory, in accordance with Section 15, Testing.

Electronic components and assemblies classified as intentional radiators in accordance with 47 CFR 15.3, Definitions, shall comply with provisions of 47 CFR 15 or 47 CFR 90, as applicable for specific devices and their operating frequencies.

Irrespective of qualification test results, Contractor shall be responsible to resolve EMC issues arising from operation of equipment in service as provided in 47 CFR 15.5, General conditions of operation.

2.10.3.2 Conductive and Inductive Emissions

Each OCS-powered subsystem shall comply with conductive emissions limits into high-voltage supply, as apportioned by the Contractor, in order to meet vehicle-level allocations per the Conductive Emission Limits section, below.

Each individual unit of power equipment shall meet the limits indicated below for vehicle-level inductive emission limits into the loop formed by the vehicle and running rails.

2.10.4 Vehicle-Level

2.10.4.1 Radiated Emission Limits

Vehicle radiated emissions shall not exceed the limits defined by the standards indicated in the table below, when measured in accordance with Section 15, Testing.

TABLE 2-10, RADIATED EMISSION LIMITS	
Frequency	**Limit**
9 kHz to 150 kHz	EN 50121-3-1, Annex C, Emission values for lower frequency range
150 kHz to 1 GHz:	EN 50121-3-1
1 GHz to 6 GHz	EN 61000-6-4, Table 3, Requirements for radiated emissions - enclosure port

Notes to Table:

1. See Section 15, Testing, for measurement methods.

2.10.4.2 Conductive Emission Limits

Conductive emissions shall have a current limit (amperes rms) defined as follows, when measured in accordance with Section 15:

TABLE 2-11, CONDUCTIVE EMISSION LIMITS	
FREQUENCY	**LIMIT**
30 Hz to 40 Hz:	10 A
40 Hz to 120 Hz:	1 A
120 Hz to 320 Hz:	10 A
320 Hz to 600 Hz:	2 A
600 Hz to 7 kHz:	Limit follows a smooth curve through 2 A at 600 Hz, 0.08 A at 2 kHz, 0.016 A at 4 kHz and 0.0046 A at 7 kHz
7 kHz to 31 kHz:	4.6 mA
31 kHz to 120 kHz:	0.5 mA

2.10.4.3 Inductive Emission Limits

The inductive emissions shall be limited as follows, when measured from rail to rail in accordance with Section 15:

TABLE 2-12, INDUCTIVE EMISSION LIMITS	
Frequency	**Limit**
20 Hz to 20 kHz:	20 mV rms
20 kHz to 31 kHz:	Linear decrease from 20 mV rms to 1 mV rms
31 kHz to 120 kHz:	1 mV rms

2.10.5 CBTC Interference

Comply with the following in regard to wireless communications required for CBTC signals:

1. The vehicle shall not produce interference that will impact the reception of CBTC wireless data communications in the bands specified in Section 21, Communications Based Train Control.
2. The vehicle shall not produce interference that will impact the reception of transponder interrogator antenna signals required for CBTC operation in Section 21.
3. The vehicle shall not interfere with existing LRV CBTC Norming Point Reader nor Doppler Radar Speed Sensing Equipment.

2.11 Exposure to Magnetic Fields

Comply with the following:

1. Exposure by passengers and Operators to static magnetic fields shall not exceed 0.5 mT.
2. Exposure to low frequency magnetic fields shall be per ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz – 100 kHz), 2010; Figure 2, Reference levels for exposure to time varying magnetic fields; according to the limit shown for general public exposure.
3. Compliance shall be tested in accordance with EN 50500.

2.12 Testability and Accessibility

Comply with the following:

1. Ensure coordination between equipment design and testing requirements.
2. See instrumentation requirements in Section 15, Testing, and PTU requirements in Section 19, System Support.
3. Test and data ports shall be directly accessible without removal of equipment. No special tools or adapters shall be required for access.

2.13 System Safety

2.13.1 General

Comply with the following:

1. Design and construct the vehicle to be safe to passengers, persons near the vehicle, and employees, both under normal operating conditions and in the event of equipment failure.
2. Ensure that all safety aspects are considered for all individual systems and subsystems, and for integrated systems (e.g. braking and propulsion) to complete the vehicle design.

3. Conflicts between performance and safety requirements shall be addressed on a case-by-case basis.

4. Where applicable, the design and construction of all equipment shall comply with:

   a. MIL-STD-882

   b. NFPA 130

   c. IEEE Std 1483

   d. 49 CFR 238.105

   e. FTA MA-90-5006-02-01

2.13.2 System Safety Program Plan

Comply with the following:

1. Develop, implement, maintain, and submit a comprehensive System Safety Program (SSP) Plan conforming to the guidelines and requirements of MIL-STD-882, Section 4, General Requirements, and where identified in the Hazard Analysis section, below, tasks within MIL-STD-882, Sections 100, Management, and 200, Analysis.

2. The purpose of the SSP Plan is to document the Contractor's safety management system approach and furnish a basis of understanding between the Contractor and SEPTA. It shall include:

   a. A description of how required tasks will be accomplished and how efforts will be coordinated and integrated with other project activities.

   b. A description of how the relevant principles of system engineering lifecycle will be implemented for this project.

   c. Project overview providing context on the applicability of the SSP Plan, including a clear summary of the Contractor's scope.

   d. A revision process for changes to the SSP Plan.

3. The SSP Plan shall clearly define the Contractor's Safety Organization showing functional relationships and lines of communication, including but not limited to:

   a. Individual staff positions and their respective responsibilities and authority, including a System Assurance Manager subject to SEPTA Approval

   b. Decision-making structures such that final authority regarding risk acceptance is clear in the event of inter- and intra-departmental conflict.

   c. An outline of resource requirements necessary for SSP execution by the Contractor.

   d. Controls for activities of subcontractors and equipment suppliers to ensure their compliance with safety requirements and objectives.

4. The SSP Plan shall include:

    a. The methods and procedures used to identify, document, and mitigate hazards during all phases of vehicle design, construction, validation and commissioning.

    b. A plan for risk mitigation verification and validation methods.

    c. A schedule of Safety Assurance activities and deliverables, sample documents, and the format for reports, analyses, and any other documents the Contractor will use in the program.

5. The SSP Plan shall verify, validate, and document that hardware, software, and related procedures comply with identified hazard management requirements as per MIL-Std-882, Task 102, System Safety Program Plan, Section 102.2.8, Verification and Validation.

6. The safety management process shall include both requirements elsewhere in the Specifications and requirements derived by the Contractor from the quantitative safety targets specified in this Section, or hazard analyses in the Hazard Analysis section, below. Employ all techniques and procedures to ensure the requirements of the SSP are accomplished.

7. The SSP Plan shall include a description of the approach for software safety assurance that applies to embedded or external software or firmware that controls or monitors safety-critical functions.

8. The SSP Plan shall contain a description of the Safety Certification methodology used and schedule of activities.

2.13.3 Safety, Reliability, and Maintainability (SRM) Progress Reports

Submit SRM Progress Reports on a quarterly basis, which shall include:

1. A qualitative description of SRM efforts and project activities.

2. A brief description of efforts made to manage each open hazard with an initial risk level of Serious or High, per MIL-STD-882.

3. New entries in the FMECA change log.

4. The status of the Hazard Management System.

5. Updated reliability prediction summary, including descriptions of any issues.

6. Updated maintainability predictions.

7. Progress and status of safety certification activities.

2.13.4 General Design Safety Requirements

The following general safety design requirements shall be incorporated into the design of all vehicle systems affecting safety:

1. Failure Modes:

    a. All safety-critical applications shall be designed to be fail-safe.

    b. An undetected failure of any device shall not permit a subsequent device failure to result in a permissive condition.

    c. Use only components with high reliability and predictable failure modes, and which have been proven in conditions similar to the project environment.

2. All systems shall function safely under all combinations of supply voltages, fluid pressures, shock, vibration, dirt accumulation, and the Project environment.

3. Software that performs safety critical functions shall be considered to fail in a potentially permissive, undetected mode and shall be verified by independent checking and self-test capability to ensure safety.

4. Circuits:

    a. Unless otherwise proven, all electronic circuits shall be assumed capable of failing in permissive modes.

    b. Systems shall be based on closed circuit principles in which energized circuits result in permissive conditions, while interrupted or de-energized circuits result in restrictive conditions.

    c. All vital circuits not wholly within the system apparatus enclosure shall be double-wire, double-break, with the exception of connections to non-vital circuits, which may be single-wire, single-break.

    d. A component or wire becoming grounded shall not cause a permissive condition. Safety circuits shall be kept free of any combination of grounds that will permit a flow of current equal to, or in excess of, 50% of the release value of any safety device in the circuit.

    e. Circuit impedances, signal encoding, shielding, layout, and isolation shall be selected to reduce the effects of interference to the extent that safety is maintained under all conditions.

5. Channels:

    a. Where applicable, provide independent channels with independent checking of each.

    b. All channels shall indicate a permissive state in order for the controlled system to achieve a permissive state.

    c. Failure in any channel shall not affect any other channel, or force the system into a permissive state, unless other actions are required by other parts of the Specifications.

d. Differences in state between channels shall be alarmed and shall force a restrictive state on the system.

6. Signals:

a. Commands that result in permissive conditions shall be propagated by minimum two independent signals, both of which shall be present before the permissive condition can occur. The lack of either signal shall be interpreted as a restrictive command.

b. Variable level signals:

- A zero signal level shall result in the most restrictive condition
- At least one enabling signal, independent from the variable-control signal, shall be present before the control signal can modulate the system to a more permissive level.

c. Digital signals:

- Systems controlled by digital transmission of commands or data shall use methods such as data redundancy or multiple transmission of messages in diverse forms to ensure the accurate reception of such signals.
- Digital message transmission reliability protocols shall be built into the transmission of such messages to ensure that they represent current commands or data, and that they are received with full message integrity.
- Failure to receive a digital signal in a timely manner, or with indications of corrupt data, shall default the function to the most restrictive condition.

7. Overcurrent Protection:

a. Circuit breakers and fuses shall be guaranteed by the manufacturer to successfully interrupt rated currents.

b. Circuit breakers and fuses shall be applied such that the maximum circuit fault currents cannot exceed the manufacturer's guaranteed operating ranges. These evaluations shall consider system voltages, temperatures, and any other factors that may affect the rating.

c. All protective devices shall be designed to accommodate the worst-case duty cycle of the system in which they are located without triggering into the fault mode.

8. Systems that rely on structural integrity for safety shall have sufficient safety factors such that failures are not possible within the life of the vehicle under all possible normal conditions.

9. Systems and devices subject to wear shall not wear to permissive states within a period no less than three times the overhaul period under the worst-case combination of duty cycle, environment, and all other influences. Such systems and devices shall be clearly indicated as SAFETY CRITICAL in the maintenance manuals.

10. Mechanical systems:

a. Systems that apply force to achieve safe states shall not depend upon the application of fluid pressure or electrical energy, unless specifically **approved**.

b. Locks, catches, and similar devices affecting safety shall be either self-engaging without application of power, or, if engaged by application of power, shall remain fully and safely engaged in the absence of power.

11. Identification: All safety related systems, and devices within those systems, shall be clearly identified as SAFETY CRITICAL in all maintenance manuals, procedures, and training materials.

2.13.5 General Operational & Maintenance Safety Requirements

Comply with the following:

1. The vehicle shall present a safe, hazard-free environment to passengers, and all operating and maintenance personnel.

    a. Personnel shall not be exposed to tripping hazards, sharp points and edges, lethal or injurious voltages, toxic materials, abrupt or unexpected accelerations, or similar hazards.

    b. Equipment location, illumination levels, colors, graphics, and surface finishes shall be selected to maximize visibility of step edges, windscreens, controls, and other objects with which the passengers and SEPTA personnel will interface.

2. Maintenance, operating, training, and other manuals shall clearly identify all hazardous materials and equipment.

    a. All maintenance procedures involving hazards shall contain clear identification of the hazard and instructions to minimize or eliminate the hazards during the conduct of the procedure.

    b. Maintenance manuals, procedures, and training shall indicate the proper handling, storage, and disposal of hazardous materials. Safety related maintenance shall be emphasized and consistently labeled throughout manuals and procedures (i.e. Warning or Caution labels).

    c. Exposure of maintenance personnel to lethal or injurious voltages shall be minimized through compartmentalization, interlocks, and similar measures.

3. Identification:

    a. All equipment enclosures containing hazardous materials, lethal or injurious voltages, sharp edges or other risks shall be clearly labeled on both the outside and inside of the equipment enclosures.

    b. Clearly label equipment containing hazardous materials, lethal or injurious voltages, or other risks on both the outside and inside of the equipment.

4. Human Error:

    a. All systems shall minimize unsafe conditions resulting from human error. No sequence of operations, or the simultaneous activation of any controls, shall result in unsafe conditions. Where conflicting commands, such as simultaneous power and brake, are requested, the more restrictive shall result.

    b. Maintenance of safety-related equipment shall be arranged such that the effects of errors are minimized. Employ methods such as limitation of adjustment ranges, unalterable software, non-interchangeable parts, and visible wear indicators as **approved** by the engineer.

2.13.6 Failure Induced Hazards

Comply with the following:

1. Design and construct vehicle equipment and systems to revert to safe modes under failure conditions.

2. Use high quality components, proven systems, redundancy, checking devices, and other techniques to accomplish this goal.

3. Vehicle systems whose failure could result in hazards of Severity Category I or II severity as per MIL-STD-882 shall conform to both of the following design principles:

    a. The failure of a single device shall not result in a permissive condition.

    b. An undetected failure of any device shall not permit a subsequent device failure to result in a permissive condition.

2.13.7 Fire and Life Safety

Comply with the following:

1. All vehicle components and systems shall be designed for the prevention of fire and protection of the public, employees, and emergency response personnel from injury due to fire, smoke, explosion, or panic due to fire, and protection of system elements from damage by fire or explosion.

2. All vehicle components and systems shall be in accordance with the fire safety requirements of 49 CFR 238 and NFPA 130 Chapter 8, Vehicles, except where more restrictive requirements are imposed by the Specifications.

3. Perform and submit a Fire Safety Analysis as required by 49 CFR 238.103(c), documenting all design and test efforts taken to comply with the requirements of the Specifications.

4. Document all hazards identified during the Fire Safety Analysis in the Hazard Management System.

5. The vehicle design shall provide for equipment to be located outside of the passenger compartment, whenever practical, in order to isolate potential ignition sources from combustible materials.

6. Design vehicle end-caps and the floor to prevent propagation of an underfloor fire to the vehicle interior. Provide fire-stops at floor and roof penetrations. Locate enclosures for control and other critical equipment to provide protection against environmental contamination and mechanical damage.

2.13.8 Hazard Identification

Comply with the following:

1. Identify all failure-induced and normal operating (non-failure condition) hazards falling into severity Categories I, II, III and IV. Compile and maintain hazards in the Hazard Management System (HMS).
2. In addition to those hazards identified by the Contractor, the following hazards shall be included in the listings and shall be considered hazards of Category I or II severity:
    a. Emergency brake fails to apply when requested.
    b. Service brakes fail to apply when requested.
    c. Propulsion fails to cease when requested.
    d. No-motion detection system indicates no motion when vehicle is moving.
    e. Door opens spontaneously when not commanded.
    f. Door opens on wrong side of vehicle.
    g. Door closes on person's limb and indicates door closed and locked to the control system.
    h. Door interlocks erroneously indicates door is closed and locked.
    i. Door open and gap filler (if equipped) does not deploy at high platform.
    j. Steps change from low to high, or vice versa, when not commanded (if steps are internal to the vehicle).
    k. Door opens before associated steps are in commanded position.
    l. Steps retract before associated door closes (if steps are external to the vehicle).
    m. Vehicle moves with steps deployed (if steps are external to the vehicle).
    n. Excessive currents or overheated equipment cause fire hazard.
    o. Indication of uncoupled when not uncoupled.
    p. Vehicle moves in wrong direction.
    q. Vehicle speed and track curvature combine in such a manner as to cause a Vehicle to derail or overturn.
    r. Onboard equipment causing EMI affecting wayside signaling system or other onboard systems.
    s. Wayside equipment causing EMI affecting wayside signaling system through vehicle or onboard systems.
    t. Uncoupled vehicle incorrectly detected as coupled.
    u. Emergency brake fails to stop at required safe braking distance.

v. Service brake fails to provide requested braking rate.

w. CBTC fails to detect overspeed condition.

x. CBTC fails to safely brake vehicle when required.

y. Loss of safety grounds, or other failure, that exposes persons to injurious voltages.

2.13.9 Hazard Management

2.13.9.1 Hazard Management in the SSP

Comply with the following:

1. Develop a hazard management process describing a hazard tracking system in accordance with MIL-STD-882, Task 103, Hazard Management Plan, and Task 106, Hazard Tracking System.
    a. The process shall define hazard identification and risk analysis, assessment, mitigation, and acceptance methods.
    b. Process steps shall be documented in the Hazard Management System (HMS) specified in the Hazard Management System section, below.
2. Assess severity and probability of a hazard's potential consequence using MIL-STD-882 categories. The SSP Plan shall document methods of determining qualitative and quantitative probability.
3. Describe the general decision-making process for risk mitigation in the SSP Plan. Mitigations shall observe the hierarchy of risk controls in MIL-STD-882, summarized below in order of decreasing effectiveness:
    a. Elimination of the hazard through design selection.
    b. Design alteration.
    c. Incorporation of engineered features or safety devices.
    d. Warning devices.
    e. Incorporation of signage, procedures, training, and personal protective equipment (PPE).
4. Initial risk levels with a severity of Catastrophic or Critical per MIL-STD-882 shall not be mitigated solely by signage, procedures, training, or PPE.
5. Residual risk levels of High per MIL-STD-882, are prohibited. Residual risk levels of Serious are acceptable only if the Contractor demonstrates that further mitigations are not reasonable or practicable, and that the design conforms to local, state, and federal requirements.
6. Define a clear process for residual risk transferal to SEPTA.

2.13.9.2 Hazard Management System (HMS)

Comply with the following:

1. Develop an HMS using a format agreed to by SEPTA and initiate with the output of the PHA.
2. Update the HMS with hazards resulting from each subsequent hazard analysis conducted or as otherwise identified.
3. Maintain the HMS throughout the project in table format in Microsoft Excel or another **approved** format.
4. Enter each hazard so that the hazard scenario, risk assessment, and resulting risk mitigation is clear when read from left to right.
5. Hazards shall not be deleted from the HMS.
6. When a hazard has multiple potential cause, each cause shall be entered as a unique entry to the HMS, with its own risk assessment and mitigations.
7. At each issuance of the HMS and with every SRM Progress Report, include a table showing the count and current status of all hazards in the HMS.
8. Review HMS mitigations and all derived safety related requirements to ensure adequate coverage of safety related testing.
9. Hazard mitigations shall identify construction specification and design criteria conformance evidence to support the closure of the hazard as the project progresses
10. Hazard mitigations shall be linked to the causes to clearly demonstrate that all causes have been mitigated for each hazard.
11. At the end of the project, all risks shall have been mitigated to an acceptable level using the hierarchy of risk controls specified in the Hazard Management section, above.
12. Residual risks may be transferred to SEPTA only with SEPTA Approval.

2.13.10 Hazard Analysis

2.13.10.1 General

Comply with the following:

1. Adjust and amend all hazard analyses as the vehicle design and construction progresses, while maintaining alignment with the HMS.
2. Select the analysis methods as appropriate for the system under evaluation and the category of hazard severity. Hazards of Category I and II severity as per the Hazard Identification section, shall by rigorously analyzed to adequately demonstrate that the hazard has been mitigated as low as reasonably practicable.

3. Perform and submit the analyses specified in this section.

2.13.10.2 Preliminary Hazard Analysis (PHA)

Comply with the following:

1. Perform a PHA in accordance with MIL-STD-882, Task 202, Preliminary Hazard Analysis.
2. The PHA shall be organized as a structured and systematic brainstorming exercise with the participation of the system design leads.
3. The hazards identified in the Hazard Identification section shall be included in the PHA when applicable and shall be considered hazards of Category I or II severity.
4. Hazards documented in the PHA shall be entered in the HMS, constituting initiation of the HMS.
5. Submit a PHA Report.

2.13.10.3 System Hazard Analysis (SHA)

Comply with the following:

1. Perform and submit a SHA in accordance with MIL-STD-882, Task 205 System Hazard Analysis, to identify and evaluate hazards resulting from the vehicle interacting with its direct interfaces at its system boundaries, such as Operators, maintainers, passengers, track, OCS, and signaling system.
2. Hazards documented in the SHA shall be entered in the HMS.
3. Submit an SHA Report.

2.13.10.4 Subsystem Hazard Analysis (SSHA)

Comply with the following:

1. Conduct an SSHA in accordance with MIL-STD-882, Task 204, Subsystem Hazard Analysis with participation from the Contractor’s subcontractors and suppliers.
2. Hazards documented in the SSHA shall be entered in the HMS.
3. Submit SSHA Report.

2.13.10.5 Failure Modes, Effects, and Criticality Analysis (FMECA)

Failure Modes, Effects and Criticality Analysis (FMECA) is a quantitative hazard analyses in which all known component or system failure modes for each applicable LRU/LLRU are considered along with their outcomes.

1. Perform and submit a FMECA to identify weaknesses in safety critical system hardware and software design, and to analyze the modes and effects of failures whenever these details are not established by historical records of equipment operation.

2. The FMECA shall provide input to system designs and to the safety analyses for theoretical circuit behavior, random component failures, electrical interference, systematic component failures, and software errors in software-based logic.

3. The analysis shall assume that each single item failure, as its effects are analyzed, is to be considered the only failure in the system.

4. The FMECA shall clearly define the scope of review to ensure completeness and define any assumptions made to perform the analysis as well as the source of quantitative failure rates used.

5. Where a single item failure is non-detectable, the analysis shall be extended to determine if the effects of a second failure, which in combination with the first undetectable failure, could result in a Catastrophic or Critical failure condition. When applicable, these identified combinational failure hazards shall be captured in the Fault Tree Analysis.

6. All single safety critical failures shall be detectable and the system shall immediately alert the Operator.

7. The system shall ensure a subsequent failure does not induce a falsely permissive mode.

8. The FMECAs developed by the Contractor and system and subsystem suppliers shall use a MIL-STD-1629 or other standard format. Submit a template for the FMECA within the SSP Plan.

9. Update the FMECA throughout vehicle design development.

10. Failure modes resulting in a Catastrophic or Critical severity level per MIL-STD-882 shall be entered in the HMS.

2.13.10.6 Operating and Support Hazard Analysis (O&SHA)

Perform an O&SHA as a workshop exercise involving SEPTA Operators and maintenance personnel. Use MIL-STD-882, Task 206, Operating and Support Hazard Analysis, as a guide for this analysis.

1. Emphasize the role of human factors in creating hazardous situations on, near, or involving the vehicle.

2. Address hazards resulting from specific maintenance activities listed in the Maintenance Allocation Chart section, below, and perform systematic review of operational and maintenance manuals.

3. Submit Safety Data Sheets (SDS) for all material recommended for use on the vehicles that are subject to the Workplace Hazardous Materials Information System (WHMIS).

4. Ensure that warnings, as required to mitigate identified hazards associated with the SDSs, are included in the operations and maintenance manuals.

5. Ensure that all parties verify that required mitigations are in place to prevent or address hazards. Make recommendations to mitigate hazards related to the vehicle service and maintenance and identify these recommendations in the O&SHA analysis.

6. Enter hazards documented in the O&SHA in the HMS.

7. Submit an O&SHA Report.

2.13.10.7 Fault Tree Analysis

Comply with the following:

1. Submit a Fault Tree Analysis (FTA) estimating the probability of a hazard's consequence from a Boolean logic model of the failure mechanisms of the vehicle system, using the FMECA and hazard analyses as inputs in conjunction with other factors such as human errors.

2. The top level events shall include, but not be limited to:

    a. Collision

    b. Derailment

    c. Fire/explosion/smoke

    d. Electrocution

    e. Door and side-door steps hazards

3. The FTA shall demonstrate quantitatively that the residual hazard rate is less than 10^{-8} per hour of operation and 10^{-7} per hour of operation for failures resulting in severity levels of Catastrophic and Critical per MIL-STD-882, respectively.

4. For hazards with multiple consequences, the probability distribution of consequence for each consequence's severity shall be considered, with the most serious risk rating being used.

5. Update the HMS with FTA data.

6. Submit an FTA Report.

2.13.10.8 Sneak Circuit Analysis (SCA)

Perform an SCA for safety critical functions to identify inherent design flaws that may cause occurrence of an unwanted function or the inhibition of a desired function by evaluating unexpected current paths, timing, labels, and indicators that may exist in the design.

1. The analysis shall consider the following sneak conditions:

    a. Sneak paths: Unexpected paths along which current, energy, or logical sequence flows in an unintended direction.

    b. Sneak timing: Events occurring in an unexpected or conflicting sequence.

    c. Sneak indications: Ambiguous or false displays of system operating conditions that may cause the system or Operator to take an undesired action.

   d. Sneak labels: Incorrect or imprecise labeling of system functions (e.g., system inputs, controls, displays, and buses) that may cause an Operator to apply an incorrect stimulus to the system.

2. Identify and evaluate all potential unwanted functions or potentially inhibited functions, in the absence of or concurrent with component failure.

3. For each sneak condition identified, redesign the system to eliminate the condition.

4. The SCA shall be performed according to a Capability Level 3 or above SCA process, in accordance with AIAA S-102.2.5.

5. The use of diodes to eliminate sneak paths is prohibited.

6. Enter all hazards resulting from the SCA in the HMS.

7. Submit an SCA Report.

2.13.11 Software Safety

Comply with the following:

1. The requirements for software safety are in addition to the requirements of Section 18, Systems and Software Engineering, and shall meet or exceed the requirements of 49 CFR 238.105 and IEEE Std 1483.

2. The SSP Plan shall include a software safety section that applies to embedded and external software or firmware that controls or monitors safety-critical functions.

3. It shall be the responsibility of the Contractor to ensure that software is subjected to these requirements continuously through the evolution of the program, including any software revisions made by the Contractor up to and including the passage of the last vehicle out of warranty.

4. Submit a standalone Software Safety Program Plan that specifically addresses the requirements of 49 CFR 238.105.

5. Software safety requirements shall treat software as an integral part of a hardware/software system.

6. A Software Configuration Item (SCI) shall be considered safety critical if it contains vital or safety related software functions, unless an independent redundant hardware means is also provided to accomplish the same functions and the hardware/software design has been analyzed and proven to be fail-safe.

7. The software safety program shall include a description of how the following will be accomplished:

   a. Definition.

   b. Implementation and oversight of the software design and verification process.

c. Integrity of the documentation.

d. Software hazard analysis.

e. Software safety reviews.

f. Software hazard monitoring, reporting and tracking.

g. Software integration with hardware at each stage of the design and testing process for components, subsystems, systems, vehicles, and trains incorporating software for safety-critical functions.

2.13.12 Safety Certification Program

The Federal Transit Administration (FTA) requires a certification program to address safety and security.

1. Participate in the Safety Certification process and furnish supporting documentation to facilitate audits of the Safety Certification documentation, as required, by the FTA.
2. Conditional Acceptance of vehicles is contingent upon completion of Safety Certification.
3. Per FTA-MA-90-5006-02-01, perform Safety Certification tasks including but not limited to:
   a. Identifying certifiable items.
   b. Developing safety and security design criteria.
   c. Developing and completing of design criteria conformance checklist.
   d. Performing construction specification conformance.
   e. Identifying additional safety and security test requirements.
   f. Performing testing and validation in support of the Safety Certification program.
4. Perform a Threat and Vulnerability Assessment (TVA) for physical security risks to the Vehicle.
5. The TVA shall include a workshop exercise with SEPTA at least 30 days prior to the submittal of the TVA.

2.14 Reliability

2.14.1 General

This section includes reliability targets and demonstration requirements. Additional reliability requirements for specific equipment may appear elsewhere in the Specifications.

2.14.2 Reliability Requirements

The following are definitions specific to the reliability requirements:

1. Relevant Failure:
    a. An independent fault in the system, while operating within its design and environmental limits per the Specifications, which results in a temporary or permanent loss of function causing a train delay or requiring corrective maintenance.
    b. Intermittent software faults, whether verified or unverified, and failures occurring as a result of operation, maintenance, or testing of the item due to Contractor-furnished documentation.
2. Excluded Failures:
    a. Secondary failures (i.e., a failure occurrence in equipment of another subsystem due to the primary failure).
    b. Failures due to vandalism or physical mistreatment at a human interface.
    c. Failures due to operating or weather conditions beyond those specified in this Section.
3. Train Delay: An event causing a trip to be any one of the following:
    a. Minimum of 6 minutes late at its destination terminal.
    b. Canceled either at its original terminal or en route.
    c. Rerouted.

2.14.2.1 Mean Distance Between System Component Failures (MDBSCF)

Vehicle systems shall meet the Mean Distance Between System Component Failures (MDBSCF) requirements specified below:

1. Assumption: Maintenance, preventive and corrective, is performed as recommended by the Contractor.

2. MDBSCF: The ratio between the total operating distance, d, and the total number of relevant failures for identical components on all vehicles, F.

3. Mean Time Between Failure (MTBF): The ratio between the total operating hours, t, and the number of relevant failures for identical components on all vehicles, F.

4. Equipment furnished by the Contractor shall be considered as belonging to one of the subsystems specified below in Table 2-13:

TABLE 2-13, MDBSCF REQUIREMENTS	
Subsystem	**MDBSCF (per vehicle)**
Traction System and Dynamic Braking and Controls	240,000 km
Friction Braking (including Track Brake, Sanders, and Air Supply System)	320,000 km
General and Auxiliary Electrical System	240,000 km
Auxiliary AC Inverter and LVPS	480,000 km
Pantograph	640,000 km
Battery	4,800,000 km
Miscellaneous Electrical	3,200,000 km
Heating, Ventilation, and Air Conditioning System	320,000 km
Door System and Controls	193,000 km
Trucks and Suspension (Including Load Leveling System)	800,000 km
Vehicle Body and Appointments, including seating, windows, cab equipment	800,000 km
Couplers and Draft Gear	1,930,000 km
Communication and Passenger Information Systems	480,000 km
Trainlines and Networks	482,804 km

5. Lighting shall meet the MTBF requirements specified in Table 2-14:

TABLE 2-14, LIGHTING SERVICE LIFE REQUIREMENTS	
Subsystem	**MTBF (per vehicle)**
LED Lamps	Mean service life of a minimum 50,000 hours (at 70% luminescence).
LED Power Supply	500,000 hours

2.14.3 Mean Distance Between Train Delay (MDBTD)

Comply with the following:

1. The vehicle fleet shall meet reliability requirements for its life based upon single vehicle operation with an average speed of 20 km/h (12 mph) and an average of 64,000 km (39,768 mi) per vehicle year.

2. Furnish equipment that meets the specified Mean Distance Between Train Delay (MDBTD) requirements, considering all failure modes for components, assemblies, subsystems and system elements, the combination of which shall result in realization of the following:

   a. MDBTD = 82,000 km (50952 miles).

2.14.4 Reliability and Maintainability Program (RMP)

2.14.4.1 RMP Plan

Submit an RMP Plan detailing how the maintainability and reliability requirements of the project will be met, including:

1. Objectives and scope of the reliability and maintainability programs.
2. A chart of the Contractor's Reliability and Maintainability organization, showing functional relationships and lines of communication, including subcontractors.
3. Controls for activities of subcontractors and equipment suppliers, to ensure their compliance with reliability and maintainability requirements and objectives.
4. The RMP schedule, identifying specific tasks with start and completion dates, and encompassing coordination and integration with major program milestones for design, manufacturing, and testing.
5. The process for coordination, review, and control of supplier reliability and maintainability efforts.
6. A control process for ensuring reliability and maintainability targets are met, including:
    a. A minimum reliability or maintainability threshold below which corrective action will be taken.
    b. Method of calculation of reliability and maintainability values.
    c. The frequency with which current reliability and maintainability values will be calculated and compared to the minimum reliability and maintainability requirements.
    d. A plan for corrective action if reliability values or maintainability values or both are insufficient.
7. Verification of product history and experience that demonstrates that specified MTBSCF, MTBF, and MDBTD requirements are achievable.
8. A description of the Failure Reporting and Corrective Action System (FRACAS) to provide for the identification, tracking, and repair of all product/process failures.
9. Failure Review Board (FRB) description, activities, and procedures.
10. Demonstration testing plans for verification of compliance with reliability requirements where calculations are inconclusive after the Reliability Demonstration Period.
11. Preventive maintenance tasks and estimates of Mean Time to Repair (MTTR) for corrective maintenance tasks for all systems and major equipment subsystems.

2.14.5 Reliability Prediction

Comply with the following:

1. Submit a reliability prediction summary report for all vehicle systems, which demonstrates that the specified vehicle and system level MDBSCF, MTBF, and MDBTD requirements will be achieved.

2. Base the calculation on the annual average operating distance, as specified in the Reliability section.

3. Reliability predictions shall use reliability block diagrams to justify estimates for the system as a whole. Reliability block diagrams shall be created in accordance with MIL-HDBK-338, Section 6.4.4.1, Reliability Block Diagrams.

4. Reliability block diagrams shall use established software of the Contractor's choice (e.g., Isograph Reliability Workbench, ITEM Toolkit, or Relyence RBD), subject to Approval.

5. Field failure data may be used to establish predicted part failure rates when similarity of design and operating environment can be demonstrated and there is a statistically significant and meaningful history of part failures.

6. If no meaningful history is available, use industry standards, recommended practices, handbooks or when applicable, use the Part Stress Method of MIL-HDBK-217 for the "ground mobile" environment.to determine part failures.

7. Maintain and update the reliability prediction summary report through the entire design, testing, manufacturing, delivery, and warranty periods.

8. As part of the SRM Progress Report, submit the reliability prediction updates or as requested by the Engineer, as the project progresses. Updates shall report on design or manufacturing changes, or problems that may affect vehicle reliability.

9. Use reliability predictions during design and development to compare competing designs, perform design tradeoffs, detect overstressed parts, and identify high failure rate items.

10. Document the methodology for satisfying the system reliability requirements and apportionment of MDBTD targets per subsystem.

2.14.6 Reliability Demonstration

2.14.6.1 Reliability Demonstration Plan (RDP)

Submit an RDP, which shall include the following to illustrate compliance with specified MDBSCF, MDBTD, and MTBF requirements:

1. Reliability demonstration schedule, excluding unit delivery and burn-in time.

2. Reliability demonstration procedures and forms for submitting and recording data, including details on the FRACAS and organization of the FRB in accordance with the Failure Review and Corrective Action System (FRACAS) Section.

3. Method for calculating MDBSCF, MDBTD, and MTBF values for individual components, subsystems, systems, and the vehicle as a whole.

4. Pass criteria demonstrating compliance of reliability requirements.

5. Process for addressing non-compliant reliability by design changes.

6. Procedures for triggering and implementing design changes.

7. Reliability demonstration report format and content.

2.14.6.2 Reliability Demonstration Period

The reliability demonstration period for each vehicle begins 60 days after the vehicle is placed in passenger service and ends two years after it is placed in passenger service.

1. Relevant failures occurring in the first 60 days in passenger service are not included in the reliability demonstration, and mileage during this 60-day period shall not be used in the calculation of the MDBF, MDBTD, MDBSCF, and MTBF values but shall be recorded and tracked in the FRACAS.

2. If the vehicle has not met the reliability requirements during or at the end of the demonstration period, implement necessary design changes, modifications, repairs, adjustments, and replacements on all vehicles to achieve the required reliability targets.

   a. Acceptable reliability data shall be obtained by another demonstration period of at least six months on the modified vehicles.

   b. Credit may not be taken for elapsed time since previously failed tests, and the specified performance and other required characteristics of the equipment shall not be changed to achieve reliability requirements.

3. Submit a Failure Analysis Report (FAR) for each failure occurrence within seven calendar days of the event. The FAR shall identify the unit and vehicle affected, the equipment involved, the cause(s) of failure, what corrective action is necessary, and shall describe the extent of such action.

2.14.6.2.1 Contractor's Corrective Actions

Comply with the following:

1. Identify the cause of failures and prepare recommendations for corrective action.

2. Corrective actions shall be incorporated in all undelivered vehicles prior to delivery, and spare parts.

2.14.6.2.2 Failure Reporting and Corrective Action System (FRACAS)

Comply with the following:

1. Establish a FRACAS in accordance with MIL-HDBK-2155, or an **approved** alternative standard.

2. The FRACAS shall collect, analyze, and record all relevant failures; analyze to the LLRU to determine cause; document the corrective actions taken; and verify the corrective actions taken were monitored for effectiveness.

3. The FRACAS shall begin at the start of factory acceptance testing of the first vehicle and shall continue through the completion of the reliability demonstration period for all vehicles.

4. Maintain an electronic FRACAS database and analyze FRACAS data to identify failure trends and fleet defects.

5. The FRACAS database shall include the status of the FAR associated with each incident. A count of items by status shall be maintained in a FRACAS status tally submitted with each SRM Progress Report.

6. Failure data analysis shall promptly identify every failure trend and determine its cause. A failure trend is defined as failure of three or more identical systems or sub-systems employed in identical or equivalent applications within a 90-day time period, where the failures are the result of the same failure mechanism.

7. FRACAS data shall include failure rates of components that have a failure ratio equal to at least half of the rate at which a Fleet Defect would be declared as defined by Commercial Provisions.

8. Implement **approved** corrective or preventive action or both for each trend. Summarize these findings and actions in the SRM Progress Report.

2.14.6.2.3 Failure Review Board (FRB)

Comply with the following:

1. Establish an FRB to determine the relevance of failures, review failure trends, determine the need for and depth of root cause failure analyses, and ensure that adequate corrective action is taken in a timely manner, using the FRACAS.

2. The FRB shall be formed prior to the beginning of the Reliability Demonstration Period and conclude at the end of the last vehicle’s reliability demonstration period, or with the resolution of the last failure brought to the FRB, whichever is later. The FRB shall meet at least once each month during this time.

3. Core FRB members shall include the System Assurance Manager, QA Manager and SEPTA reliability and warranty representatives. Other Contractor and subcontractor representatives shall participate as necessary to facilitate thorough review of failure data.

4. All equipment failures that occur during the warranty period shall be classified as relevant or excluded failures by the FRB. In the event of disagreement within the FRB, SEPTA has final authority on classification of a failure.

5. Maintain a database of all failures, relevant and excluded, that were reviewed by the FRB.

6. Open failures in the database shall be included in each Reliability Demonstration Report.

2.14.6.2.4 Reliability Demonstration Reports

During the Reliability Demonstration Period, submit on a monthly basis, a Reliability Demonstration Report that includes:

1. Vehicle-level MDBSCF and MDBTD calculations.
2. System-level MDBSCF and MDBTD calculations.
3. MDBSCF calculations for any systems within 110% of the Reliability requirements of this Section, and any other systems as requested by SEPTA.
4. The current FRACAS database FAR status tally.
5. Open items from the FRB failure database.
6. A description of actions taken to improve reliability, with an assessment of their impact.

2.15 Maintainability

2.15.1 General

Objectives of the Contractor's Maintainability Program shall be to enhance vehicle availability, improve worker safety, minimize maintenance costs, and minimize vehicle downtime through careful selection and scheduling of corrective and preventive maintenance activities.

2.15.2 Mean Time to Repair (MTTR)

Comply with the following:

1. System MTTR predictions shall calculate the subsystem weighted average MTTR using the LRU/LLRU failure rates and their respective MTTR.
2. System weighted average MTTR shall be calculated using subsystem failure rates and their respective MTTR.
3. The following equation shall be used for both calculations:

$$MTTR = \frac{\sum_{n=1}^{m} \lambda_n * T_n}{\sum_{n=1}^{m} \lambda_n}$$

   a. MTTR is the Mean Time To Repair for the system or subsystem.

   b. m is the number of subsystems/LRUs/LLRUs that make up the system or subsystem.

   c. λ_n is the subsystem/LRU/LLRU failure rate.

   a. T_n is the average time required to repair the respective equipment units following a failure (corrective maintenance), expressed in hours.

4. Diagnostic time shall be included in the MTTR values (all values are person-hours).

5. Submit proposed MTTR values with full justification, if different from specified MTTR, at the system level as part of the Reliability and Maintainability Program (RMP) Plan.

6. Per MIL-HDBK-470, MTTR is comprised of various elements including preparation time, fault isolation time, disassembly time, interchange time, reassembly time, alignment time, checkout time, and start-up time. This MTTR shall be the weighted average of the MTTR of the system elements specified in Table 2-15, MTTR Requirements.

TABLE 2-15, MTTR REQUIREMENTS	
System Element	**MTTR (hours)**
Vehicle Body & Appointments	2.13
Propulsion, Dynamic Brake & Controls	1.77
Friction Braking, including load leveling controls	1.94
Electrical	1.50
Auxiliary Power System	1.50
HVAC	2.12
Communications (except communications front end)	0.82
Passenger Doors & Controls	0.84
Lighting	0.50
Couplers & Draft Gear	1.50
Trucks & Suspension, including load leveling suspension elements	1.57
CBTC	1.00
Total	17.19

Table Notes:

1. Time for specific tasks shall not exceed the following:
    a. Replace powered truck wheel and axle set: 6.0 person-hours.
    b. Replace HVAC unit: 1.5 person-hours.
2. Relative accessibility of components, measured in time to gain access, shall be included in MTTR values.
3. Servicing (excluding interior and exterior cleaning) shall be restricted to checking and replenishing oil, grease, and other fluids; cleaning or replacing filters; checking battery electrolyte; inspecting brake pads; and downloading fault logs.
    a. Servicing shall not be required more often than every 16,000 km and shall not require more than 1 hour in elapsed time or more than 2 person-hours per vehicle.
4. Systematic fault isolation procedures shall be developed for inclusion in maintenance manuals. The Engineer may Approve subsystem MTTRs that take more time than specified,

if the average for any system element is not changed significantly and total MTTR hours for the vehicle are not exceeded.

2.15.3 Scheduled and Preventive Maintenance

Maintenance includes the tasks necessary to service the vehicle, to defer or prevent failures, and to maximize equipment life:

1. Scheduled maintenance tasks shall be defined in the Preventive Maintenance and Servicing Manual specified in Section 19, System Support, and shall be no more frequent or take more time than specified in Table 2-16, Service Levels Schedule, below.

2. Reliability Demonstration and Maintainability Demonstration shall assume the service levels specified in Table 2-16, with no augmentation.

TABLE 2-16, SERVICE LEVELS SCHEDULE	
Cycle (Days)	**Scheduled Maintenance Person (in Hours)**
15	6
60	8
180	24
360	36
1,800	250
3,600	1200 (First Major Overhaul)

2.15.4 Maintenance Allocation Chart

Comply with the following:

1. Develop and submit a Maintenance Allocation Chart (MAC) as defined in APTA PR-IM-RP-002-98 outlining all schedules and activities for corrective and preventive maintenance. The MAC is a chart or table used to determine the following:

    a. What items require maintenance.

    b. What maintenance is required on those items.

    c. What type of knowledge or skill is required to perform that maintenance.

    d. When the maintenance is required.

    e. MTTR Prediction.

    f. How long each task will take to complete.

    g. What consumable items are required.

    h. What spare parts are required.

i. What type of facility is required.

2. Maintenance recommendations shall be based upon the Contractor's and suppliers' experience.

3. The MAC shall list all tools and test equipment required to maintain the vehicle, including the following:

   a. Tool or test equipment number.

   b. Full name of the item.

   c. SEPTA Class/Lot number.

2.15.5 Maintainability Demonstration

Comply with the following:

1. Submit a Maintainability Demonstration Plan (MDP) that includes a schedule for all Maintainability Demonstrations, and any necessary special emphasis demonstrations.

2. Maintainability demonstrations shall be performed by SEPTA maintenance personnel.

3. Preventive maintenance, troubleshooting, change-out of components, corrective maintenance, and use of special tools shall be demonstrated as part of the training program for maintenance personnel. Maintenance of safety critical functions shall be addressed.

4. Demonstrations shall be performed using the Maintenance Manuals.

5. Maintainability demonstrations shall be completed 60 days after the delivery of the of the first vehicle.

6. Upon delivery of the first vehicle, perform a vehicle-level demonstration of maintenance tasks, per MIL-HDBK-470, Appendix B, Maintainability Test and Demonstration Methods.

2.16 Contract Deliverables Requirements List (CDRL)

2-1 Vehicle Curve Capabilities
2-2 General Arrangement Drawings and Renderings
2-3 Vehicle Detail Dimensions
2-4 Weight Plan and Calculations
2-5 Vehicle Excursions
2-6 Radio Interference Study and Design Package
2-7 WRIS Plan and Schedule
2-8 WRIS Report
2-9 Load Compensation Design Package
2-10 Propulsion System Performance
2-11 Emergency Brake System Design Package
2-12 No-Motion Detection Design Package
2-13 EMI/EMC Design Package
2-14 System Safety Program (SSP) Plan
2-15 Safety, Reliability, and Maintainability (SRM) Progress Reports

2-16 Fire Safety Analysis (FSA)
2-17 Hazard Management System (HMS)
2-18 Preliminary Hazard Analysis (PHA)
2-19 System Hazard Analysis (SHA)
2-20 Subsystem Hazard Analysis (SSHA)
2-21 Failure Modes, Effects & Criticality Analysis (FMECA)
2-22 Operating and Support Hazard Analysis (O&SHA) Report
2-23 Fault Tree Analysis (FTA)
2-24 Sneak Circuit Analysis (SCA)
2-25 Software Safety Program Plan
2-26 Threat and Vulnerability Assessment (TVA)
2-27 Reliability and Maintainability Program (RMP)
2-28 Reliability Prediction Summary Report
2-29 Reliability Demonstration Plan (RDP)
2-30 Failure Analysis Report (FAR)
2-31 Reliability Demonstration Report
2-32 Maintenance Allocation Chart (MAC)
2-33 Maintainability Demonstration Plan (MDP)

2.17 CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested
5. Software functional descriptions: Include top level control parameters and values

2-1 Vehicle Curve Capabilities:

1. Evidence that the vehicle can operate within specified limits on the specified horizontal and vertical curve radii.

2-2 General Arrangement Drawings and Renderings:

1. Plan, profile, and front elevation drawings of the vehicle exterior, showing visible features, with dimensions.
2. Plan view of seating arrangements, including seat dimensions and spacing, aisle widths, accessible on-board circulation path, mobility aid parking areas, bicycle areas, and doorway dimensions.

3. Longitudinal section drawings and 3-D renderings of the vehicle, showing seating arrangements, stanchions, interior steps, cab, wind screens, portable device charging stations, and similar features.

    a. Seating arrangements shall include longitudinal, transverse, and a combination of both seating arrangements, with and without windscreens and comply with Section 14, Interior and Exterior Appointments.

4. Plan view drawing of roof equipment, with dimensions.
5. Plan view drawing of under-floor equipment, including trucks, with dimensions.

2-3 Vehicle Detail Dimensions:

1. Detail drawings of vehicle and systems:

    a. Show compliance with specified Vehicle Weights and Dimensions.
    b. Include the location of center of gravity, with vertical, lateral, and longitudinal coordinates.

2-4 Weight Plan and Calculations:

1. Furnish plan view of the vehicle showing standing space.
2. Show required and predicted weight of completed and ready-to-run AW0 vehicle, including all fluids.
3. Furnish calculations for each of the weights AW0 through AW4.
4. Present, in table form, the predicted weights of all major subsystems comprising the AW0 weight, in the initial weight report. Subsystem weights shall sum to predicted AW0 weight.
5. Include actual weights in the table as they become known as part of the Monthly Progress Report, as specified in Section 20, Program Control and Quality Assurance.

2-5 Vehicle Excursions:

1. Drawings showing dynamic vertical and horizontal excursions of the vehicle under normal and worst-case conditions of truck and suspension motions and vehicle body roll on tangent track:

    a. Show vehicle clearance dimensions with maximum suspension deflection and maximum body roll.
    b. Identify the location of the roll center(s).

2. Tables showing excursions as under 1, above, with representative curve radii, including the minimum specified curve radius.

2-6 Radio Interference Study and Design Package:

1. Submit a radio interference study to confirm compliance with the requirements specified in the Radio Frequencies section.

2-7 WRIS Plan and Schedule:

1. Narrative of how the Wheel Rail Interface study will be carried out, including the following:

    a. Study procedures
    b. Personnel involved
    c. How the various parties will be coordinated
    d. Schedule for conducting the study

2-8 WRIS Report:

1. Narrative of how the study was carried out
2. Vehicle geometry including the following:

    a. Truck spacing
    b. Axle spacing
    c. Wheel diameter
    d. Wheel back-to-back spacing

3. Vehicle dynamic characteristics including the following:

    a. Mass for each vehicle section at AW0 and AW4
    b. Truck mass
    c. Wheelset mass
    d. Secondary/primary stiffness (X, Y, Z) and damping values
    e. Allowable rotation to bump stops
    f. Allowable vertical deflection to bump stops

4. Track condition inputs including the following:

    a. Minimum curvature
    b. Minimum/maximum gauge

5. Wheel profile and rail profile drawings.
6. Section view of wheel and rail in nominal contact position and flange contact position.
7. NYTRAM section drawing for worst case curving.
8. Calculation of undamped/damped natural frequency for the primary/secondary along with a calculation of critical damping percentage.
9. Demonstration of compatibility among the following:

    a. Chosen rail sections
    b. Track design
    c. Vehicle truck design
    d. Wheels

10. Details of how these are optimized for long term wheel and rail wear, minimum propensity to derail, wheel/rail noise reduction, and ride quality enhancement.

2-9 Load Compensation Design Package

2-10 Propulsion System Performance:

1. Tractive effort curves and line current for motoring from zero to the vehicle design speed at AW0, AW1, and AW2, for line voltages of 325, 630, and 750 Vdc. The charts shall include the factors needed to convert effort to torque and speed to rpm.
2. Braking performance curves and brake line-current, including emergency braking, from the vehicle design speed to zero, at AW0, AW1, AW2, AW3, and AW4 showing apportionment between dynamic, friction braking, and track brakes for 750 Vdc and 630 Vdc. The charts shall include the factors needed to convert effort to torque and speed to rpm.
3. Speed/time/distance curves for motoring and braking at 325Vdc and 630 Vdc and at AW0, AW1, AW2, AW3, and AW4.

2-11 Emergency Brake System Design Package

2-12 No-Motion Detection Design Package

2-13 EMI/EMC Design Package:

1. Description of the design approach used to ensure that specified EMC and EMI requirements are met and that proper emphasis is placed on the control of interference, interface design, and FCC requirements.
2. List of vehicle-borne EMI sources.
3. List of vehicle-borne equipment potentially susceptible to this interference.
4. Failure conditions proposed techniques and methods for resolution of potential EMC problems.

2-14 System Safety Program Plan:

1. Plans, documents, and analyses demonstrating that the vehicle is safe, and complies with this Section, and other safety requirements in the Specifications.
2. At a minimum, include the following:

   a. A hazard listing, as described in this Section.
   b. Failure analyses, both top-down and bottom-up, as appropriate and as **approved** by SEPTA, demonstrating that the hazards identified will not occur.
   c. Sneak circuit and single-point of failure analysis.
   d. Other analyses, drawings, material property data sheets, or other information appropriate for demonstrating safety.

2-15 Safety, Reliability, and Maintainability (SRM) Progress Reports

2-16 Fire Safety Analysis (FSA)

2-17 Hazard Management System (HMS)

2-18 Preliminary Hazard Analysis (PHA)

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2-28 Reliability Prediction Summary Report

2-29 Reliability Demonstration Plan (RDP)

2-30 Failure Analysis Report (FAR)

2-31 Reliability Demonstration Report

2-32 Maintenance Allocation Chart (MAC)

2-33 Maintainability Demonstration Plan (MDP)

2.18 Referenced Standards

The following standards are referenced in this Section:

47 CFR 15	Radio Frequency Devices
49 CFR 38, Subpart D	Light Rail Vehicles and Systems
47 CFR 90	Private Land Mobile Radio Services
AIAA S-102.2.5	Performance-Based Sneak Circuit Analysis (SCA) Requirements
DOT-FTA-MA-26-5005-00-01	Hazard Analysis Guidelines for Transit Projects
EN 50121-3-1	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Train and complete vehicle
EN 50121-3-2	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock – Apparatus
EN 50155	Railway applications – Rolling Stock. Electronic equipment

EN 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
EN 50128	Railway applications - Communication, signaling and processing systems - Software for railway control and protection systems
ICNIRP	Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz – 100 kHz)
IEC 60850	Railway applications - Supply voltages of traction systems
IEC 61000-4-1	Electromagnetic compatibility (EMC). Testing and measurement techniques. Overview of IEC 61000-4 series
IEC 61000-4-2	Electromagnetic compatibility (EMC). Testing and measurement techniques. Electrostatic discharge immunity test
IEC 61000-4-3	Electromagnetic compatibility (EMC). Testing and measurement techniques. Radiated, radio-frequency, electromagnetic field immunity test
IEC 61000-4-5	Electromagnetic compatibility (EMC). Testing and measurement techniques. Surge immunity test
IEC 61000-4-6	Electromagnetic compatibility (EMC). Testing and measurement techniques. Immunity to conducted disturbances, induced by radio-frequency fields
IEC 61000-4-8	Electromagnetic compatibility (EMC). Testing and measurement techniques. Power frequency magnetic field immunity test
IEC 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
IEC 61287	Railway applications - Power convertors installed on board rolling stock
IEC 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
IEEE 1478	IEEE Standard for Environmental Conditions for Transit Railcar Electronic Equipment
IEEE 1483	Standard for Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control
ISO 2631	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems

END OF SECTION

Table of Contents

Table of Figures

3.1 General

3.1.1 Scope

These requirements apply to all vehicle structural elements above the trucks, including articulation joints and related structures, and equipment mounting points, but exclusive of any composite body cladding panels, if used, except as noted.

3.1.2 Configuration

Configure vehicle as specified in Section 2, Design and Performance Criteria.

1. Body sections: Articulated and semi-permanently coupled together with articulating joints to form a single operating vehicle.

2. Vehicle structure: The vehicle-body structure shall comply with the Streetcar requirements of ASME RT-1 and the Specifications. Where there is a conflict the most conservative shall apply.

3. Clearance: Design vehicle and attached equipment to meet specified wayside clearances for the specified track profiles, and specified vehicle-to-truck clearances, except for stops attached to the vehicle body for limiting truck movement.

4. Equipment location and protection: No control equipment, except coupler and friction brake control equipment, is permitted below the floor between the powered truck and the anticlimber.

5. Interfaces to wayside equipment: Provide interfaces for lifting, hoisting, and rerailing as permitted by the low-floor vehicle body and as **approved**.

6. Weight: Optimize the vehicle-body structure to meet limits specified.

3.1.3 Exterior Flatness Before Finishing

Comply with the following:

1. Construct raw exterior surfaces to be free of ripples and buckles prior to application of any fillers to the body.

2. Maximum allowable variation from a straight line, or the designed curved line, prior to application of any fillers, is as follows:

    a. 2.4 mm (3/32 in) (peak to valley) in 914 mm (36 in) measured in any direction for all side, end, and roof surfaces not hidden by covers or shrouds.

    b. 7.9 mm (5/16 in) (peak to valley) in 914 mm (36 in) measured in any direction for surfaces hidden by covers or shrouds.

3.1.4 Materials

Comply with the following:

1. Vehicle structures: Aluminum, HSLA steel, stainless steel, or a combination of these materials.

2. Vehicle non-structural exterior elements: May be FRP or similar service-proven materials, as **approved**.

3. For specific material and painting requirements, see Section 16, Materials and Workmanship.

3.1.5 Construction Methods

Comply with the following:

1. Vehicle-body structure: Welded connections designed in accordance with AWS D1.1/D1.1M or **approved** equivalent, per the requirements of Section 16, Materials and Workmanship.

2. Structural fasteners: High-strength lock bolts, as **approved** for primary structure. Secondary structure or brackets may be joined with bolts, rivets, or welding. All fasteners and attachments shall comply with the requirements of Section 16, including for dissimilar material connections.

3. Skins: FRP or other **approved** material, bonded or welded to the side-frame posts and rail using fixtures to hold the skin during curing or welding, per Section 16.

4. Interchangeability: Like subsystems, equipment, and components shall be completely interchangeable between vehicles. Welds, bolt patterns, and bonding shall be identical on all vehicles.

3.1.6 Venting and Drainage

Provide venting and drainage throughout the vehicle body to prevent build-up of condensation:

1. Vent enclosed structural cavities.

2. If subject to rusting or oxidizing, treat in accordance with the paint and coating requirements of Section 16, Materials and Workmanship.

3.1.7 Definitions

The following definitions apply to terms used in this Section:

Crash Energy Management (CEM)

A design technique that enhances crashworthiness. CEM seeks to control the load path into the vehicle-body structure and to absorb the energy with components that are outside the occupied volume.

Failure

The complete separation of a member such that it can no longer perform its intended function—the rupture point on the stress-strain curve.

Load Factor

A number by which the actual or specified load is multiplied in computing the calculated stress. The load factor shall include all applicable safety factors.

Margin of Safety (MS)

$$MS = \frac{\text{Allowable Stress}}{\text{Calculated Stress}} - 1$$

The calculated stress shall include the applicable load factors. MS shall be a minimum value, but a positive number.

Permanent Deformation

A member is considered as having developed permanent deformation if one of the following conditions is met:

1. The minimum yield strength as published by ASTM for the specified material and grade is exceeded.

2. For materials or grades not covered by an ASTM specification, the minimum yield strength as guaranteed by the manufacturer is exceeded.

3. The material has buckled or deformed and will not return to its original shape or position after the load is released.

For materials without a specific yield point, the 0.2% offset method shall be used to determine yield strength.

Ultimate Load Carrying Capacity

The maximum load that a member can support before it completely fails as a column.

3.1.8 Verification of Design

Verify the design as follows:

1. Perform required analyses.

2. Perform tests on the finished vehicle shell in accordance with Section 15, Testing, to verify conformance of vehicle structures with Specification requirements and requirements of the Contractor's design, and to validate the design analyses.

3.2 Structure Arrangements

3.2.1 General

Comply with the following:

1. Design portions of the roof, side frame, and underframe to form a girder to carry the specified static and dynamic loads.

2. Select type and thickness of material to be used to maximize strength and reliability, minimize weight, and produce the desired appearance.

3. Incorporate tie down points into the vehicle in order to secure the vehicle for shipment and for body straightening after an accident.

4. Structural connections:

   a. Rivets or bolts in combination with welds shall not be considered to share the load with the welds. Welds or bonds shall carry the entire load across the connection.

   b. Design strength of the connection shall exceed the ultimate load-carrying capacity of the weakest member joined.

   c. Structural fasteners shall comply with the Special Requirements for Structural Fasteners section in Section 16, Materials and Workmanship.

   d. Threads in tension carrying more than 11 kg (25 lb) are prohibited unless specifically **approved**.

5. Camber and deflection: Incorporate camber and control deflection to permit all equipment, including side doors, to operate satisfactorily under variations of load from AW0 to AW4, and to interface with platforms in compliance with Section 2, Design and Performance Criteria.

3.2.2 Cab Ends

3.2.2.1 Cab End Frame Structure

Comply with the following:

1. Provide a cab end frame structure consisting of the following:

   a. Partial height collision posts at the approximate one-third points (horizontal plane) of the end frame (but in any case, maximum 915 mm (36 in) apart) welded to the top and bottom of the end sill and structural shelf;

   b. Structural corner posts at each vehicle body corner welded to the top and bottom of the end sill, structural shelf, and roof;

   c. A horizontal beam ("structural shelf") at the bottom of the windshield tying the tops of the collision posts to each other and to the corner posts.

2. The design shall accommodate a wide, single-piece windshield that maximizes Operator field of view and compliments the **approved** appearance.

3. The design shall accommodate the energy absorbing bumpers specified in the Energy Absorbing Bumper section, below.

4. Crashworthiness:

   a. Securely weld the above elements to the end frame sheathing, underframe, side frame, and roof as appropriate, to resist telescoping in collisions, such that the connection can support the ultimate strength of the members being joined.

   b. Provide equivalent anti-telescoping and crashworthy elements at the articulation joint and support structure that provide the same performance as the cab end structure.

Alternative structural arrangements with equal or better performance may be proposed, with appropriate supporting technical justification, for **approval**.

3.2.2.2 Anticlimber

Provide anticlimbers at each end of the vehicle that comply with the following requirements:

1. Location: Extended laterally over the full width of the vehicle front end frame.
2. Connection: Welded or bolted to the end sill, providing uniform shear resistance over the anticlimber width.
3. Engagement: Designed to engage the anticlimber of an opposing vehicle under the worst horizontal and vertical track curves.
4. Ribs: Sufficient protrusion or depth to ensure positive engagement in all curves and potential impingement from cover materials.
5. Tow bar anchor: Located at the center of the anticlimber, the same as the existing fleet, to attach tow bar when towing or being towed by legacy vehicles (see Appendix D).
    a. Towing shall include both pushing and pulling another vehicle.
    b. Shall be compatible with the SEPTA existing tow bar.
    c. Shall be of sufficient strength to tow or be towed by any legacy vehicle or new vehicle under AW3 condition.
    d. The vehicle-body structure, including the tow bar anchorage and anticlimber, shall be capable of withstanding forces greater than 110% of the ultimate strength of the tow bar in tension and compression without permanent deformation.
6. Height and Configuration:
    a. Such that opposing anticlimbers of like vehicles and other rail vehicles sharing the route engage over the full range of vertical and horizontal vehicle-body motions.
    b. Where necessary to provide structural compatibility with multiple types of rail vehicles, provide additional anticlimbing engagement capacity that meets the same requirements as those specified for the anticlimber.
7. Jacking pad: Provide under the center of each anticlimber, with sufficient capacity to rerail the end of the vehicles with a margin of safety of 2.
8. Cover: Frangible plastic to cover the anticlimber ribs and produce a visual impression similar to an automotive bumper.
    a. It shall not deter engagement of anticlimbers in a collision.
    b. It shall be separate from the bumper and the cab end enclosure.

3.2.2.3 Cab End Enclosure

Design the cab ends as follows:

1. Enclose the cab ends, below the anticlimber, with a full-width, smooth, rounded enclosure, designed to deflect road vehicles and pedestrians. It shall not interfere with the energy absorbing of the shell structure. Some, or all, of the enclosure may form the cladding for the energy-absorbing bumper, below.

2. Continue cab end enclosure to meet the side body and skirts such that there is no visible gap except a flexible element, if required, to accommodate the energy-absorbing bumper.

3. Design with ground clearance as low as feasible; maximum 203 mm (8 in).

4. Coordinate the cab end enclosure with the anticlimber cover, coupler access cover, and energy-absorbing bumper to comply with design requirements and produce an overall aesthetically pleasing appearance as **approved**.

3.2.3 Underframe

Comply with the following:

1. Underframe material shall be stainless steel, except where **approved** by SEPTA.

2. Incorporate end sills, draft sills, body bolsters, transverse articulation beams, side sills, and body sills designed to carry and transmit the design loads through the structure.

3. Any failure of the vehicle body, due to accident or collision, shall begin in the end structure outboard of the coupler support structure, rather than in the center section, articulation, or the region between the articulation and the coupler support. Design shall fail by progressive buckling rather than by shearing of structural elements or failure of connections between elements.

4. Design shall allow clearance for trucks, couplers, and other equipment, and accessibility for maintenance and removal, consistent with SEPTA’s facilities. It is the responsibility of the Contractor to familiarize itself with SEPTA’s maintenance environment.

5. The design of the underframe shall provide for continuity of flanges and webs at all locations where load-bearing members intersect.

3.2.4 Side Frame

Comply with the following:

1. Include window posts, door posts, longitudinal roof rails, longitudinal window top and belt rails, and appropriate sheathing and stiffeners.

2. Include full-height structural posts at the sides of all door and window openings (continuous between the side sill and the roof rail). Incorporate gussets and other stiffeners to reinforce connections to meet design load requirements.

3.2.5 Floor

3.2.5.1 General

Design and construct the floor to meet applicable vibration and strength requirements in the Specifications.

3.2.5.2 Floor Structure

Comply with the following:

1. Transverse beams: Provide to transmit vertical floor loads to side sills and for support of floor panels.
2. Longitudinal beams: Provide a continuous side sill and support members.
3. Steps:
   a. Material: Stainless steel.
   b. Locations: High- to low-floor transitions in main body sections.
   c. Dimensions: Width to equal that of the center aisle. Risers shall be of equal height. All dimensions are subject to design review and **approval**.
   d. Fire endurance: Comply with same requirements as the floor.
   e. Surface: Flooring material and step-edge nosing per Section 14, Interior and Exterior Appointments, and Section 16, Materials and Workmanship.
4. Floor panels shall not be considered structural and shall comply with the following:
   a. Material: Composite floor panels, as specified in Section 16, Materials and Workmanship, or **approved** equal.
   b. Support: Attach to the floor beams, end sills, side sills, body sills (if used), and body bolsters, depending upon location.
   c. Transverse joints: Locate over primary structural members or specifically designed substructure.
   d. Insulation: Provide elastomeric tape between panel and metal structure.

3.2.5.3 Floor Profile

Design floor with a slight slope at doorways to allow water to drain to the outside. Slope shall extend inwards from the doorway 18 to 24 inches and shall be sufficient to prevent pooling of water, nominal 2% over sloped section, or as **approved**. See Section 2, Design and Performance Criteria, for floor height at the doorways.

3.2.5.4 Floor Fire Requirements

Design floor to withstand specified fire requirements and fire performance tests specified in Section 15, Testing. If an alternate floor design for fire safety is proposed, submit the following:

1. Detailed design of the proposed floor
2. Detailed description of the proposed standard
3. Evidence of compliance to the standard
4. Evidence that the proposed floor design yields safety to passengers and the Operator equal to a floor compliant with the standards specified in Section 15 in the event of a vehicle fire

3.2.5.5 Subfloor

Comply with the following:

1. Provide a subfloor (floor pans) below the floor beams throughout the length of the vehicle. The subfloor shall not be structural unless **approved**:
   a. Design: Shall not permit the entrance of water into the vehicle body.
   b. Material: Stainless steel.
   c. Thickness: Minimum 0.5 mm (0.02 in).
   d. Assembly: Weld to bottom flanges of floor beams and to draft sills, end sills, side sills, and body bolsters.
   e. Seams and edges: Permanently watertight and fireproof.
2. If clearances prohibit the application of the subfloor pan at individual locations, alternative designs may be proposed that produce the specified watertightness, noise, and fire barrier properties.

3.2.5.6 Floor Insulation

Comply with the following:

1. Fill the space between the floor and subfloor with insulation in accordance with Section 14, Interior and Exterior Appointments.
2. If clearances yield less than normal separation between the subfloor and floor panels, alternative designs may be proposed that satisfy the specified thermal and acoustic insulation and fire rating requirements.

3.2.6 Roof

3.2.6.1 General

Construct the roof of carlines, purlines, and roof sheathing covering the entire roof area.

3.2.6.2 Roof Fire Requirements

Design roof to withstand the fire performance tests specified in Section 15, Testing. If an alternate roof design for fire safety is proposed, submit the following:

1. Detailed design of the proposed roof
2. Detailed description of the proposed standard
3. Evidence of compliance to the standard
4. Evidence that the proposed roof design yields safety to passengers and the Operator equal to a roof compliant with the standards specified in Section 15 in the event of a vehicle fire

3.2.6.3 Roof Equipment

Comply with the following to accommodate roof-mounted equipment:

1. Provide framing members and structural wells for support of roof-mounted equipment.
2. Provide equipment wells with adequate drainage for the worst-case environmental conditions described in Section 2, Design and Performance Criteria.
3. Provide roof equipment, including wiring and pipe work, so as to present a clean and simple appearance when viewed from above.
4. The roof shall be properly reinforced and braced to support the weight, stress, and vibration of roof mounted apparatus.

3.2.7 Articulation

Comply with the following:

1. Articulation:
    a. Considered an integral part of the vehicle body, including during testing required by the Specifications.
    b. Shall provide connection between vehicle-body sections to allow the sections to rotate with respect to each other in both the horizontal and vertical planes. It shall incorporate physical stops that prevent over rotation.
2. Articulation Bellows: Cover on the inside as an integral part of the interior finish. See Section 14, Interior and Exterior Appointments, for additional articulation requirements.
3. Maintenance Access: Articulation components that require periodic service, inspection, and maintenance shall be easily accessible either from the passenger compartment, side of the vehicle, or bottom of the vehicle at inspection pit.

4. Friction Material:

    a. If the articulation uses friction material for rotation, it shall have adequate life over a scheduled heavy maintenance interval but not shorter than 60 months.

    b. Material shall provide a coefficient of friction as constant as possible so that turning at curves is smooth and consistent over time without excessive flanging of the adjacent truck.

3.2.8 Jacking Pads and Hoists

In addition to the jacking pad specified for each anticlimber, provide each vehicle-body section with jacking pads at structural points to sustain jacking loads:

1. Features: Non-slip, easy to reach.

2. Propose a scheme after NTP with jacks, hoists, lifts, quantities, and capacity, for SEPTA purchase after Award.

3. It shall be possible to lift the vehicle by the following means:

    a. Fixed in-floor vehicle hoists (normal means of vehicle lifting in Shop).

    b. Portable vehicle lifts (for occasional lifting inside Shop).

    c. Portable jacks (for emergency lifting not in Shop).

4. Asymmetrical jacking: Clearly indicate limitations of any body-section in maintenance and re-railing instructions, such that cosmetic damage, deformation, or dislocation does not occur.

5. Diagonal jacking with adjacent articulation and vehicle-body sections attached shall not cause structural or cosmetic damage.

6. Trucks shall be retained with the body during jacking or hoisting unless intentionally disconnected. The truck-to-vehicle-body connection shall be considered safety critical.

3.3 Shrouds and Skirts

Pockets, cavities, and partially enclosed spaces shall have provisions to prevent buildup of debris, liquids, and condensation.

3.3.1 Roof Shroud

Roof shroud (if provided):

1. Aesthetics: Consistent with vehicle body styling.

2. Strength: Sufficient for worst case combination of specified wind and vehicle design speed.

3. Design: Shroud roof-mounted equipment so that, when viewed from the side, the vehicle will have unbroken lines at top and bottom.

4. Material: FRP complying with Section 16, Materials and Workmanship unless **approved** otherwise.

5. Attachment: Secure to roof structure using mechanical fasteners removable using ordinary tools.

6. Attachment where access is required:

    a. Design such that removal is not necessary for equipment access for maintenance and inspection from ladders, maintenance and inspection catwalks, or other **approved** locations.

    b. Shrouds shall be hinged, flip-down type, and removable by sliding the moveable portion of hinge pins.

    c. During closing of the shroud shall be lift-assisted.

    d. Provide quick-release closures.

    e. Sufficient to hold the shrouds firmly in place so they are rattle-free and last the life of the vehicle.

3.3.2 Skirts

Comply with the following:

1. Skirt Locations:

    a. Sides of the vehicle to enclose trucks, tow bar, open spaces that may be accessible by pedestrians along the right of way

    b. On the sides between trucks if the vehicle structure does not cover these areas

2. Specific Location Requirements:

    a. Skirts of high-floor areas below end sill: Carry around corners and down sides of vehicle to blend with line of bottom of vehicle in low floor area.

    b. Skirts of low floor areas: Form a uniform lower edge with bottom of vehicle body.

    c. Skirts in vicinity of trucks: May be modified to accommodate turning.

    d. Coordination with cab end enclosure: Design skirts to comply with the Cab End Enclosure section, above.

3. Design: Removable, not load bearing members.

4. Material: HSLA steel, aluminum, or FRP complying with Section 16, Materials and Workmanship.

5. Appearance:

    a. Skirts: Integral part of vehicle body.

    b. Ventilation openings: If required, in harmony with overall vehicle aesthetic design.

6. Repair: Skirts at ends and corners shall be readily repairable following minor collisions.

7. Attachment where access is not required:

    a. Provide standard threaded fasteners, removable with common hand tools; or

    b. Provide a key (see Section 14, Interior and Exterior Appointments, for the Key Assignment Table).

    c. Sufficient to hold the skirts firmly in place so they are rattle-free during vehicle operation and last the life of the vehicle.

8. Attachment where access is required:

    a. Design such that removal is not necessary for equipment access or maintenance.

    b. For easy access to trucks, skirts over trucks shall be hinged, lift-assisted, and removable by sliding the moveable portion off of hinge pins.

    c. Provide a means to hold the skirt in the open position when lifted.

    d. Provide quick-release closures of truck-access panels.

    e. Sufficient to hold the skirts firmly in place so they are rattle-free and last the life of the vehicle.

3.4 Structural Design Requirements

3.4.1 General

Base the structural design on the following:

1. Specified loads, load factors, deflections, and crashworthiness requirements.

2. The Contractor’s experience, for structures not covered by the Specifications, subject to successful stress analyses and testing.

3. Passive safety design concepts for vehicles, in ASME RT-1, Section 3, Interoperability.

4. Multistage CEM that has progressive controlled collapse of energy absorption zones, begins at the vehicle ends, preserves passenger and operator space, and limits collision accelerations.

5. Interoperability requirements such that based on the 1-D model below, a new vehicle will not cause more deformation when impacting an existing vehicle, than two existing vehicles impacting.

3.4.2 Interoperability

3.4.2.1 General

As a minimum, comply with interoperability requirements of ASME RT-1. These include

1. Requirements for anticlimber and leading end structure to be aligned in case of engagement, and coupler and tow bar interface to allow towing. Each of these requirements shall be met for engagement between rail vehicles of the same or different types operating on the same routes.

2. Requirements for rail vehicles operating in urban environments, intended to cause the vehicle to deflect struck objects from its path; and minimize entrapment, override, and penetration of automobiles and light trucks.

3.4.2.2 Energy Absorbing Bumper

Provide a bumper aesthetically integrated with the cab end enclosure, designed to minimize damage, to the extent possible, to struck pedestrians, cyclists, road vehicles, and other rail vehicles:

1. Bumper style: Wraparound, continuous, or segmented with separate front and corner/side segments, with corner/side segment designed to reduce damage in corner collisions.

2. Minimum bumper coverage: Full width of the vehicle and wrapped around sides minimum 450 mm (18 in).

3. Minimum vertical extent: 355 to 762 mm (14 to 30 in) above TOR, to match bumper heights of roadway vehicles.

4. Maximum rail clearance: 203 mm (8 in) from TOR to bottom of bumper.

5. Energy absorbing mechanism: Self-restoring and capable of absorbing collision energies between two trains of maximum size with the criteria for the element to be fully recoverable as follows:

    a. Closing speed of minimum 8 km/h (5 mph), and analysis as defined in ASME RT-1 Section 9.3, Crashworthiness Analysis.

    b. Under loading as defined in ASME RT-1, Table 4, Crashworthiness for Streetcars, Item 1, Collision Scenario 1 – low-severity impact scenario, there is to be no damage and the element is to be fully recoverable.

6. Stroke before anticlimber contacts struck vehicle or object: 100 mm to 150 mm (4 in to 6 in); the bumper shall absorb most of the kinetic energy before the anticlimbers mate.

7. Cladding: Cushioning and aesthetically pleasing, matching cab end enclosure colors and materials, but separate such that no part of the cab end enclosure shall be damaged under collision energies up to the restoring capacity of the energy absorbing mechanism.

8. Maintainability:

    a. Attached with bolted connections to allow easy and quick replacement following a collision.

    b. The Heavy Repair Manual specified in Section 19, System Support, shall address repair and replacement of the bumper.

    c. Submit a bumper maintainability report.

9. Vertical Stability: Provide sufficient vertical strength to prevent the bumper from bending up instead of crushing and to prevent interference with anticlimber mating during collisions.

10. Coupler access:

    a. Bumper and cladding shall be hinged to provide access to the coupler, by swinging upward.

b. The design shall include latches or other mechanisms to positively retain the bumper in both the raised and lowered positions without rattling or movement while in service.

c. Include hinges and hydraulic assist to allow the bumper and cladding to be raised by a fifth-percentile female. Include latches or other devices to retain bumper in the raised position.

d. Raising and latching of the bumper shall not contact or mar other portions of the vehicle.

e. The raised bumper shall not interfere with the crashworthiness of the vehicle.

3.4.2.3 Project-Specific Requirements

The vehicles procured under this Contract will share routes with existing vehicles and will operate in an urban environment with road vehicles.

In addition to the information provided in this Section, see Appendix A for details of existing vehicles.

1. The existing SEPTA trolley fleet was designed in the late 1970s using static-strength-based requirements.

2. The AW0 weight is approximately 16,695 kg (36,806 lb).

3. From available Builder documents, and based on industry standard practices of the time, for a 60 km/hr (37 mph) impact speed between two like vehicles, anticlimbers engaging, Figures 3-1 and 3-2, below, provide the 1-D model for the existing single-ended and double-ended vehicles.

4. It is assumed that the crush occurs within the first 1.5 m (59 in) behind the anticlimber in the underframe.

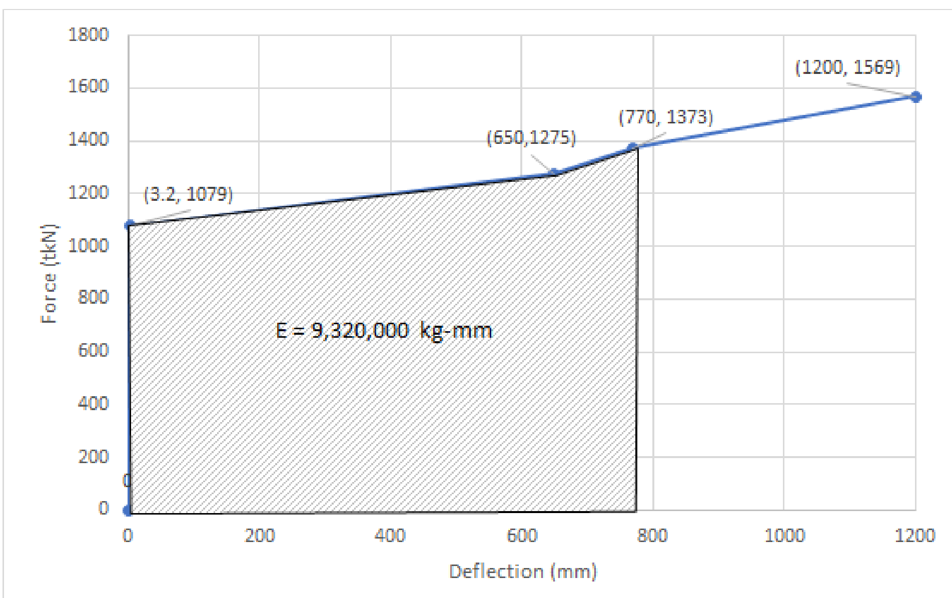


FIGURE 3-1, SEPTA EXISTING VEHICLE STIFFNESS CURVE – SINGLE-ENDED VEHICLE

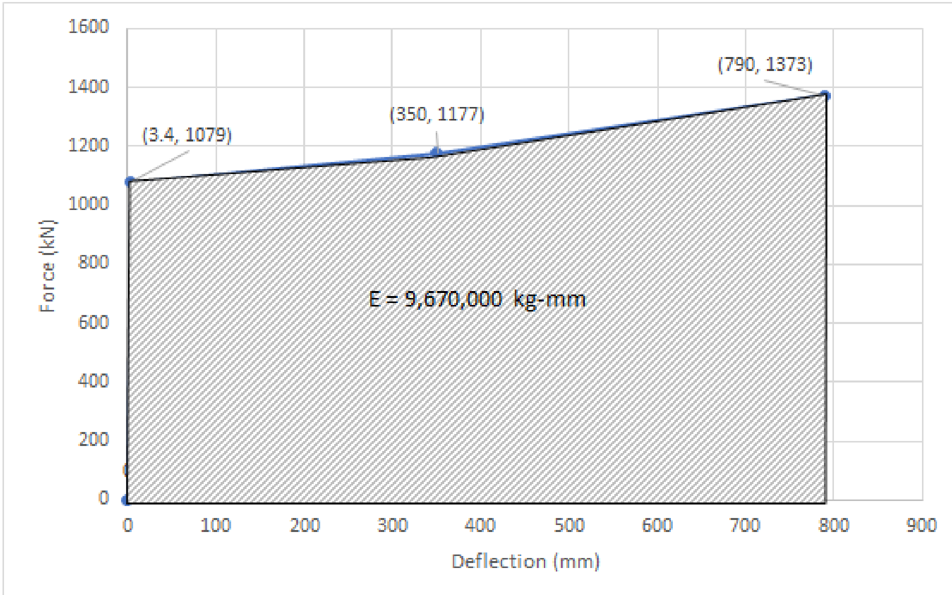


FIGURE 3-2, SEPTA EXISTING VEHICLE STIFFNESS CURVE – DOUBLE-ENDED VEHICLE

3.4.3 Crashworthiness

3.4.3.1 Design

Comply with the following:

1. Design the vehicle-body structure in accordance with ASME RT-1, including requirements of Table 2, Structural Load Requirements for Streetcars, Table 4, Crashworthiness for Streetcars, and specified testing:
    a. Static load requirements are specified below.
    b. For crashworthiness, design the structure with minimum three sequential energy absorption zones, Zone 1, Zone 2, and Zone 3 as defined in ASME RT-1.
    c. Collapse shall not commence until the end sill compression load has been exceeded, with the exception of the energy absorption in Zone 1.
    d. The required Energy Absorbing Bumper constitutes Zone 1 and shall satisfy ASME RT-1, Table 4, Crashworthiness for Streetcars, Collision Scenario 1 - low-severity impact scenario.
    e. Comply with ASME RT-1, Table 4, Crashworthiness for Streetcars, Item 2, Collision Scenario 2.
    f. For each zone, the CEM elements shall be identified.
        - Nonrepairable CEM elements shall be removable and replaceable.
2. Demonstrate compatibility with existing vehicles by 1-D analysis as specified below

3. Subject to **approval**, European standards such as EN 15227 may be proposed, if it can be shown that results are essentially equivalent to ASME RT-1 and achieve structural compatibility with the existing vehicles.

4. Quasi-static or dynamic tests on the various structural elements may be required to validate the analysis and show the actual energy absorbed by the elements during crushing, in accordance with Section 15, Testing, or ASME RT-1 Section 10.4, Crash Energy Management Tests, depending on the availability of validated models matching the specified design.

3.4.3.2 Crashworthiness Analysis

Comply with the following:

1. Demonstrate performance of the crashworthiness design features for all collisions specified in ASME RT-1, Section 9.3, Crashworthiness Analysis, and Table 4, Crashworthiness for Streetcars. This includes complying with all specified simulation conditions, speeds, scenarios, acceptance criteria, and results presentation.

    a. The material models used in the crash analysis shall be determined based on material testing and validated through analysis.

    b. CEM simulations shall consider lot variations of the maximum yield and ultimate strengths of steels when designing CEM absorber elements or main structure intended to act as absorber.

    c. A train is the maximum number of vehicles able to operate in normal revenue service as specified in Section 2, Design and Performance Criteria.

2. Demonstrate performance of the crashworthiness design features:

    a. Collision between two new vehicles:

        - Simulation conditions: ASME RT-1 Section 9.3, Crashworthiness Analysis, for new vehicle into new vehicle:
            - Vehicle closing speed: Table 4, Crashworthiness for Streetcars, Collision Scenarios 1 and 2, for the new vehicle into new vehicle
            - Acceptance criteria: ASME RT-1 Section 9.3, Crashworthiness Analysis, and Table 4, Crashworthiness for Streetcars

3. Demonstrate compatibility with existing vehicles:

    a. Demonstrate that geometries of new vehicle and existing vehicles are compatible.

    b. Perform 1-D analyses to verify models and that Specification compliance is met:

        - Scenarios:
            - New vehicle into new vehicle at the speeds in ASME RT-1, Table 4, Crashworthiness for Streetcars items 1 and 2 to verify 1-D model against 3-D models
            - Existing vehicle into existing vehicle at 60 km/hr (37 mph) to verify model can reproduce the stiffness curves above
            - New vehicle into existing vehicle at 60 km/hr (37 mph) to demonstrate compliance with the structural design requirements

3.4.3.3 Crashworthiness Analysis Interactive Review

At the discretion of the Engineer, the Engineer may require that models and results be reviewed during live interactive sessions with the engineers who performed the crashworthiness analysis, three weeks after each submittal.

1. At these sessions, give the Engineer full access to the model input and output, and use of the software on a computer.

2. Give access to view the crushing simulation on the computer.

3.4.4 Vertical Design Load Strength Requirements

3.4.4.1 Static Load

Design the completely equipped vehicle body to carry the maximum vehicle loading of weight AW4 distributed uniformly along the vehicle, less truck weight or running gear weight. Stresses shall not exceed the following:

1. 65% of the guaranteed minimum material yield strength; and

2. 65% of the buckling strength, and no loss of local stability

3.4.4.2 Fatigue Load

For fatigue-critical joints and structural details, determine allowable fatigue stress according to the requirements of the following standards and handbook:

1. AWS D1.1/D1.1M

2. AWS D1.2/D1.2M

3. AWS D1.3/D1.3M

4. AWS D1.6/D1.6M

5. AWS Welding Handbook requirements for dynamically loaded structures

6. Other recognized standards, including welding execution standards, as **approved**, for connections not covered by Items 1 to 5 above.

For each joint design, the static stress at the AW2 load shall be less than the mean stress that determines the allowable fatigue limit. The fatigue stress range shall be calculated at AW2 loading times a dynamic factor.

The dynamic factor shall be as determined by the Contractor but shall be minimum plus or minus 20% under constant amplitude loading. The fatigue limit shall be established for 10 million cycles. The fatigue stress range shall not exceed the allowable range(s) in items 1 to 6 above for a given joint detail.

3.4.5 End Sill Compression Load

The end sills shall be capable of transmitting the loads from the collision posts into the draft sill and side sills, without failure, when the posts are loaded to their ultimate strength.

Comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, End sill compression.

3.4.6 Coupler Anchorage

3.4.6.1 Coupler Anchor Compression Load

The anchorage for the coupler shall withstand tension and compression forces during towing operations of another Streetcar under worst-case conditions. Both vehicles shall be under AW3 loading.

3.4.6.2 Coupler Anchor Tensile and Compressive Loads

The vehicle-body structure, including the coupler anchorage, shall be cable of withstanding forces greater than 110% of the ultimate strength of the coupler without permanent deformation.

3.4.7 Collision Posts

3.4.7.1 Design

Comply with the following:

1. Collision posts shall be continuous, closed, cross-sections through the end sill, extending from the bottom of the end sill to the structural shelf.
2. Design the posts and supporting structures in the end frame such that when the post is overloaded, the initial failure begins as bending or buckling in the structure.
    a. Primary connections between the collision post and other structure shall not fail before the ultimate strength of the post itself is reached; failure shall occur in the post.
    b. Ultimate failure shall not be in any connections, the underframe, or roof structure, and shall not occur by shearing or fracturing of any member.
3. If the post is designed to support more than the specified load, then the supporting structure shall be strong enough to support the increased bending capacity of the posts. The posts shall fail before the supporting structure.

3.4.7.2 Collision Post Shear Load

The minimum ultimate shear strength of each collision post shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Collision post shear load.

3.4.7.3 Collision Post Load

The capacity of each collision post shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Collision post load.

3.4.8 Corner Posts

3.4.8.1 Design

Comply with the following:

1. Corner posts shall be continuous, closed, cross-sections and extend full height from the underside of the end underframe to the roof rail.

2. The connections of the posts to the supporting structure, and the supporting structure itself, shall be strong enough to develop the bending capacity of the posts.

   a. Primary connections between the corner post and other structure shall not fail before the ultimate strength of the post itself is reached; failure shall occur in the post.

   b. Ultimate failure shall not be in any connections, the underframe, or the roof, and shall not be by shearing or fracturing of any member.

3. If the posts are designed to support more than the specified loads, then the supporting structure shall be strong enough to support the increased bending capacity of the posts. The posts shall fail before the supporting structure.

3.4.8.2 Corner Post Shear Load

The ultimate shear strength of each corner post shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Corner post shear loads.

3.4.8.3 Corner Post Load

The capacity of each corner post shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Corner post loads (elastic design loads).

3.4.9 Structural Shelf

Comply with the following:

1. Design:

   a. Provide a horizontal structural shelf below the windshield connecting the tops of the collision posts to each other and to the corner posts.

   b. The outer ends of the structural shelf shall be supported by the corner posts.

2. Capacity:

   a. Comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Structural shelf.

3.4.10 Side Wall

3.4.10.1 Side Wall Load at Side Sill

Side sill and supporting structures shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Side wall load, at side sill.

3.4.10.2 Side Wall Load at Belt Rail

Belt rail (at the lower side window edge) and supporting structures shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Side wall load, at belt rail.

3.4.11 Articulation Joint and Anticlimber Loads

Resist vertical and longitudinal loads developed over the collision scenarios in the Crashworthiness Analysis section.

3.4.12 Floor Load

Meet the following conditions for a fully equipped vehicle with a vehicle weight of AW4 evenly distributed:

1. Floor panels shall deflect maximum 1/250 of the shortest span between supports, up to a maximum of 4.3 mm (0.17 in).

2. Floor beams shall deflect maximum 1/250 of the span between supports.

3.4.13 Roof Load

All parts of the roof structure and walkways shall comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Roof, concentrated load, as might be applied by maintenance personnel walking on the roof carrying tools and equipment.

3.4.14 Truck-to-Vehicle-Body Attachment

Comply with the following:

1. Trucks (or running gear): Shall be raised with the vehicle unless intentionally detached.

2. Attachment structure: Stresses shall not exceed 50% of yield with the truck or running gear hanging from the body.

3. Attachment Strength:

    a. The structural connection of the truck (or running gear) to the vehicle body shall comply with ASME RT-1, Section 4.5, Truck-to-Carbody Attachment, and the structural load requirements in Table 2 for truck-to-vehicle-body attachment; or **approved** alternate standard.

3.4.15 Equipment

3.4.15.1 Equipment Loads

Comply with the following requirements for design of equipment attachments:

1. Scope: Underfloor, roof, and interior equipment, any portion of the equipment, equipment boxes, equipment hangers, standby supports, safety hangers, and the vehicle body supporting structure.
2. Design load: At a minimum, comply with ASME RT-1, Table 2, Structural Load Requirements for Streetcars, Equipment attachments, or **approved** alternate standard.

Equipment within an equipment box:

1. Not required to meet the above criteria if it can be shown that the equipment will not penetrate the walls of the equipment box when exposed to these load levels.
2. The equipment box shall conform to these load criteria with the rearranged equipment (i.e., equipment that is presumed to have broken loose) in addition to its normal arrangement.

3.4.15.2 Equipment Fasteners and Supports

Comply with the following requirements for the support of equipment enclosures:

1. Fastenings shall be designed so that in no case will the limit of the carrying capacity of a member be the strength of one fastener or the shearing of fasteners through the base material.
2. Equipment weighing more than 12 kg (26 lb) shall not be supported by threaded fasteners in tension or shear — unless they are provided with an unstressed secondary support.
3. Equipment shall not be supported by bolts in holes tapped in the structural elements of the vehicle. However, it is permissible to use tapping plates in accordance with Section 16, Materials and Workmanship.
4. For bolts used to support equipment, the minimum diameter shall be 10 mm (3/8 in).
5. Underfloor equipment shall be mounted on rails, hangers, brackets, or support structure such that the equipment rests on the top side of the support member and thus does not rely solely on bolted connections for mechanical integrity.
6. Waivers of these requirements may be requested for enclosures that weigh maximum 12 kg (26 lb) or are agreed to be crushable, such as terminal boxes, or where the arrangement is service proven, as defined in Section 1, General Topics and Definitions.

3.4.16 Jacking and Hoisting

Comply with the following requirements:

1. For design purposes, the vehicle shall comply with the following:
    a. Symmetrical Jacking:
        - Loading condition on each jack point:
            - Vertical load: Static, AW0, with a load factor of 2; combined with
            - Horizontal load: 10% of the vertical load applied in any horizontal direction.
        - Result: No permanent deformation of any vehicle-body structure.

    b. Diagonal Jacking:
        - Scope: Vehicle-body jacking pads, jacking sockets, and supporting structure. Diagonal jacking shall be considered for each jack pad and socket adapter;
        - Loading condition: Empty vehicle with trucks (AW0 condition), under the load imposed by the diagonal jacking test of Section 15, Testing;
        - Result: No permanent deformation.

    c. Anticlimber Jacking: It shall be possible to jack and re-rail the vehicle from under the anticlimber with a single jack.

    d. It shall be possible to lock the upper articulations during jacking to avoid possible rolling or twisting while the vehicle is being jacked and while sitting on jacks.

2. The stress analysis shall include an analysis of the jack pads, jack sockets, their connections to the vehicle body, and the immediate supporting vehicle structure under symmetric jacking and the worst case of diagonal jacking.

3. The same load factors as above shall apply for hoisting.

3.4.17 Steps

If provided, steps shall be designed to support one person as follows:

1. Load: 135 kg (298 lb) per 305 mm (12 in) of tread

2. Load factor: 2

The resulting stresses in any part of the steps assembly, and its supporting structures, shall not exceed the yield strength of the material.

3.4.18 Natural Frequency

The natural frequency of each vehicle section under a vehicle weight of AW4 and supported at the articulation yokes and at the bolsters shall be minimum 2.5 times the natural frequency of the secondary suspension.

3.5 Stress Analysis

3.5.1 Purpose

Stress analyses shall be used to design the vehicle structures in compliance with the requirements of the Specifications and to obtain the lightest-weight vehicle consistent with those requirements.

3.5.2 General

Comply with the following:

1. The **approved** stress analysis is a prerequisite for **approval** of the structural test procedures and structural drawings required by the Specifications, and shall be used as an aid in determining strain gauge locations for use during testing.

2. During the design and manufacture of the vehicles, update the input to the stress analysis to reflect the as-built configuration of the structure.

3. For any portion of the proposed design that is based on a service-proven vehicle, data may be furnished from previous tests, historical data from operations, or stress analyses as required to satisfy the corresponding portion of these requirements.

3.5.3 Stress Analysis Content

Include the following as a minimum:

1. Show the calculated stresses, allowable stresses, and margins of safety for all elements for all specified loading conditions.

2. Include calculations of stresses in joints, joint elements, and other important elements. For joints modeled as intersecting plates in an FEA with stresses greater than 50% of the allowable criteria, perform additional analysis to determine the actual stress in the connection.

3. Calculate the elastic stability of plates, webs, and flanges for members subject to compression and shear.

4. Prototype and test critical connections that cannot be adequately analyzed to demonstrate compliance with the requirements of the design and the Specifications.

5. If stainless steel is used, consider the variation in the stainless-steel compression modulus with stress in calculating compressive stability of stainless-steel members.

6. See the Contract Deliverables Requirements List (CDRL) section, below, for detailed requirements.

3.5.4 Initial Stress Analysis

The initial stress analysis will require temporary assumptions as to configuration and weights. If the initial design changes due to manufacturing considerations or other factors, revise and resubmit the stress analysis.

3.5.5 Buckling Analysis

Calculate the buckling strength of structural framing members. Include each member that was found to have a calculated compressive stress greater than or equal to 35% of material yield strength in any of the analyses.

3.5.6 Finite Element Analysis (FEA)

As part of the stress analysis, perform a linear-static finite element analysis (FEA) of the complete vehicle body.

1. Purpose: To show that the vehicle body design meets the requirements of this Section.
2. FEA software: Perform analysis using a recognized computer program such as NASTRAN, ANSYS, ABAQUS, or **approved** equal.
3. Non-linear static analysis:
    a. Perform if FRP skin is used and the material or the connection between the material and the supporting structure exhibit non-linear properties.
    b. This may be instead of the linear static FEA, or a local analysis in addition to a global static analysis.
4. Interactive Engineer Review:
    a. At the discretion of the Engineer, the Engineer may require review of FEA models and results during live interactive sessions with the engineers who performed the FEA, three weeks after each submittal.
    b. At these sessions, give the Engineer full access to the FEA model input and output, and use of the software on the computer used for the analysis.
    c. Provide access to view the simulation on the computer.

3.5.7 Validation of Linear Elastic Analysis

Perform Vehicle-Shell Structural Type Tests in accordance with Section 15, Testing, to confirm the accuracy of the analysis:

1. For each test required for Vehicle-Shell Structural Type Tests in Section 15, compare the vehicle-body structural test measured results with the corresponding stress analysis analytical results.
2. Tabulate and submit this information with the vehicle-body structural test reports for each test, as required in Section 15.
3. The test and analysis results shall correlate within the following ranges:
    a. Longitudinal deflections: Within +/- 10%
    b. Vertical deflections: Within +/- 10%
    c. Stresses: Within +/- 20%

3.6 Contract Deliverables Requirements List (CDRL)

3-1 Jacking Pad Design Package
3-2 Jacking Scheme Proposal Report
3-3 Roof Shroud Design Package
3-4 Bumper Maintainability Report
3-5 Skirt Design Package
3-6 CEM and Collision Survivability Plan
3-7 Crashworthiness Analysis Report
3-8 Vehicle-Body Stress Analysis and Tests Plan
3-9 Stress Analysis Report
3-10 Equipment Support Stress Analysis Report
3-11 FEA Model
3-12 FEA Report
3-13 FEA Input and Output Data on Electronic Media

3.7 CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Component ratings: Top level components, and ratings of other components if requested

3-1 Jacking Pad Design Package:

1. Drawing showing locations of jacking pads for both maintenance and re-railing equipment.
2. Details of vehicle-body inserts, if provided, sufficient to enable SEPTA to procure adapters for portable jacks.

3-2 Jacking Scheme Proposal Report:

1. Submit within 120 days after NTP.
2. Include drawings showing locations for jacking, hoisting, and lifting the vehicle.
3. Include information on the quantities and capacities of jacking, hoisting, and lifting equipment, for SEPTA purchase.
4. Include information on how lifting the vehicle by the following means shall be accomplished:
    a. Fixed in-floor vehicle hoists (normal means of vehicle lifting in Shop)
    b. Portable vehicle lifts (for occasional lifting inside Shop)
    c. Portable jacks (for emergency lifting not in Shop)
    d. Rerailing situations representing all locations along the SEPTA alignment

3-3 Roof Shroud Design Package:

1. Drawing showing side and end views as mounted on vehicle.
2. Drawing showing details of roof shroud construction, materials, and attachment methods.

3-4 Bumper Maintainability Report:

1. Submit within 120 days after NTP.
2. Include information on procedure to replace bumper.
3. Include a list of tools necessary to replace bumper.
4. Include worker hours required to replace bumper.
5. To be updated as the design progresses.

3-5 Skirt Design Package:

1. Drawings showing side and end views as mounted on vehicle, with ventilation openings, if used.
2. Drawing showing details of skirt construction, materials, and attachment methods.
3. Drawing showing details of skirts over trucks, including hinges, lift-assist mechanism, and removal method.

3-6 CEM and Collision Survivability Plan:

1. Submit maximum 30 calendar days after NTP.
2. Include the requirement of ASME RT-1, in Sections 8 and 4, to present the design strategy that defines the specific features to meet the required zones of energy absorption.
3. Include information on the strategy to address compatibility with existing fleets.
4. Include information on how material models will be determined for each material used.
5. Include the CEM testing plan, or waiver justifications, as specified in Section 15, Testing.
6. Include information on the method of repairs for low-speed and high-speed impacts, such as time to repair, spare parts needed, and how the repairs will be included in the maintenance manuals.

3-7 Crashworthiness Analysis Report:

1. Submit minimum 60 calendar days before starting manufacture of structural parts.
2. The report shall demonstrate that the crushing of the vehicle body is stable.
3. Include sufficient analysis to demonstrate compliance with the specified requirements.

4. Organize the report and furnish sufficient detail so that the Engineer can readily follow the theory and its application to this vehicle.

5. Include the same reference information, such as drawing numbers, material properties, references for formulas, and buckling coefficients, as required in the Stress Analysis Report CDRL.

6. Include the following:

    a. Animations of the time-dependent, large-deflection analysis:

        - Format: Compatible with one of the current commonly available video formats.
        - Content: Sufficient detail, view directions, and magnifications to review the behavior and stability of the following:
            - Energy absorption elements
            - Frangible elements
            - Non-crushable structure inboard of the crush zones
            - The vehicle body as a whole
            - The train as a whole

    b. Plots of the following for the CEM portion of the vehicle and the entire vehicle:

        - Force vs deflection
        - Energy vs time
        - Velocity vs time
        - Force vs time

    c. Description of the model in sufficient detail to show that the model is appropriate for this application, including as a minimum the following:

        - Descriptions of the elements and restraints
        - The conditions of the simulation
        - The output of the simulation to show that relevant Specification requirements have been met, including force-displacement plots

    d. Description of the material models used for each material defined, including the following for each material:

        - Summary of the material testing
        - Summary of the material model validation
        - Plots of the stress vs strain curves
        - Information on lot variation of the maximum yield and ultimate strengths of steels and how it was considered

    e. Table for non-crushable structure inboard the crush zones:

        - Show locations where the MS is less than 0.20, with a discussion of the results.
        - There shall be no permanent deformation in this area of the structure.

f. References for formulas, calculation procedures, buckling coefficients, material strengths, and other physical and mechanical properties that appear in the report.

- If a cited reference is not readily available to the Engineer, furnish the following:
    - Reference; or
    - Copies of the pages that show the cited formula or data, and the pages that show the development and interpretation of the formula or data
- References shall be in the English (USA) language:
    - If an English (USA) reference cannot be found, furnish an English (USA) translation
    - Include both the original and the translation in the report

g. Test reports required to verify the results of the analysis:

- Include the entire test report, which shall include the test procedure, raw data, reduced data, and a summary
- The Engineer will determine the adequacy of the submitted test reports

h. Electronic input and output files.

3-8 Vehicle-Body Stress Analysis and Tests Plan:

1. Submit within 30 days after NTP.
2. Follow the general requirements of the Stress Analysis Report.
3. This Plan shall be submitted and **approved** before **approval** of the Stress Analysis Report.
4. Update and resubmit whenever the Plan for the analysis and testing of the vehicle body is revised, but not more often than monthly.
5. With each revision submit detailed revision notes that explain each change and indicate where changes were made in the report as a result of the change.
6. Include the following:

a. Table including the Specification subsection or standard met, load case number, load, and criteria.
b. Outline of the procedure the Contractor will use to analyze and test the design of the vehicle body.
c. Listing of load conditions to be used during analysis and test, with load magnitudes, supports, and points of application.
d. Description of the analysis to be used for each load condition.
e. Structural sketch of the vehicle body, showing sheathing thickness, framing member locations and shapes, and the materials and thicknesses of each. Define methods of joining.
f. Diagrams of load applications and supports
g. Procedure for analyzing the static and fatigue capability of FRP side skin and its connections, if used.
h. Table of material properties.
i. Description of major assumptions.

j. Description of how analysis results will be correlated with test results, as required in Section 15, Testing.

3-9 Stress Analysis Report:

1. Submit as follows:

   a. Initial stress analysis report: Within 90 days after NTP.
   b. Complete stress analysis report: Minimum 60 days before starting manufacture of any vehicle body structural parts.
   c. Revisions: Any time the design, or the stress analysis plan is updated but not more than monthly.

2. With each revision, include detailed revision notes that explain each change and indicate where changes were made in the report as a result of the change.

3. General Requirements:

   a. Final submitted and **approved** Stress Analysis Report shall be for vehicle in as-built configuration.
   b. Certify that analysis and calculations have been reviewed and checked before submitting report.
   c. Follow procedure outlined in Vehicle-Body Stress Analysis and Tests Plan.
   d. Report shall demonstrate that structure satisfies requirements of Contractor's design and the Specifications.
   e. Report shall be sufficiently complete and analysis sufficiently accurate for SEPTA to use report to design repairs during life of vehicles.
   f. Organize report in a logical way such that content can be easily found by the Engineer. Furnish sufficient detail so the Engineer can readily follow the theory and its application to this vehicle.

4. Include the following:

   a. Sections that organize the material into logical units.
   b. Consecutive page numbering.
   c. Table of Contents Listing each section with page number on which it starts.
   d. Manual analysis: Each page shall be initialed by analyst and checker, and include the following:

      - Date
      - Revision level
      - For revisions, include revision letter with revision date and initials of analyst and checker

   e. Computer-generated analysis: Each page shall be initialed by checker and include the following as a minimum:

      - Page number
      - Date
      - Revision level

5. Include the following drawings:

   a. **Approved** structural sketch of the vehicle body showing structural elements and their connections (submitted with the Vehicle Body Stress Analysis and Tests Plan, above).
   b. Framing and miscellaneous drawings:

      - Underframe and bolster - plan, elevations, and sections
      - Anticlimbers - plan, elevations, and sections
      - Side frame(s) - plan, elevations, and sections
      - Roof frame - plan, elevations, and sections
      - End frame - plan, elevations, and sections
      - Drawbar attachment to underframe - plan, elevations, and sections

6. In drawings, or body of the analysis, indicate materials and weights of all components.

7. In body of analysis, include the following:

   a. References for formulas, calculation procedures, buckling coefficients, material strengths, fatigue strengths, and other physical and mechanical properties where these items appear in the stress analysis:

      - If a cited reference is not readily available to the Engineer, furnish the reference or copies of the pertinent pages. In addition to the pages that show the cited formula or data, include the pages that show the development and interpretation of the formula or data.
      - References shall be in English (USA). If an English reference cannot be found, furnish an English translation. Include both original and translation in report.

   b. Algebraic statement of formulas and equations before related calculations are performed. Define terms, and state values and units to be applied to these terms.
   c. Units for each quantity.
   d. Diagrams displaying, for each load case, loads applied externally to the vehicle body and points of support.
   e. Analysis showing compliance with each design load and condition, as required by Section 3.4, Structural Design Requirements.
   f. Detailed calculations of stresses with Margins of Safety (MS) in all structural framing members and sheathing, with a summary of the results.
   g. Table showing locations where MS is less than 0.20, along with design or operating conditions (loads) that cause the stresses.
   h. Reference to particular elements including, but not limited to the following:

      - Side sill
      - Body sills (if used)
      - End sill
      - Anticlimber
      - Draft sills
      - Tow bar supports
      - Coupler anchorage
      - Side frame rails

- Side frame posts
- Transverse and longitudinal sections at doorways
- Body bolster
- Floor and floor beams
- Collision posts
- Corner posts
- Structural shelf
- Articulation end frame
- Roof structure
- Equipment supports
- Connections between structural elements
- Any FRP skin and bonded connections used

i. Tabulation or diagram of calculated deflections of vehicle body under full vertical loading and under combined vertical and compression loads specified in:

   - Section 3.4.4, Vertical Design Load Strength Requirements;
   - Section 3.4.5, End Sill Compression Load; and
   - Section 3.4.7, Collision Posts.

j. Analysis of critical and highly loaded connections, as required in Section 3.4.4, Vertical Design Load Strength Requirements, showing joint is stronger than weakest member being joined.
k. Analysis of the strength of connection of trucks to vehicle body, including calculated vertical and horizontal connection capacities.
l. Analyses of the vehicle-body structure under:

   - Torsional loading resulting from diagonal jacking described in Section 3.4.16, Jacking and Hoisting Loads; and
   - Torsional loadings resulting from anticipated normal operations.

m. Tabulation of Contractor's selection of:

   - Allowable fatigue stresses, with sources; and
   - Assumed applied fatigue stress ranges for structural members and connections that are critical in fatigue, and for FRP skin and its connections if used.

n. Table showing engineering properties of each grade and temper of each material used in vehicle structure:

   - Include material designation, yield strength, ultimate strength, elongation, Young's modulus for tension, and compression and shear elastic moduli.
   - For each, use minimum-guaranteed values for grade and heat treatment of material used, from the specifications.
   - Do not include in the table materials, grades, or tempers not used in vehicle body construction.

o. Table showing geometric properties, such as area and section moduli.

p. Table(s) showing minimum static and fatigue strengths of single and multiple spot welds:

- Give values for each material, temper, weld size, and thickness combination used in vehicle body.
- Include source of data.

q. Test reports (if tests are conducted to furnish necessary data). Submit entire test report, which shall include test procedure, raw data, reduced data, and summary.

3-10 Equipment Support Stress Analysis Report:

1. Submit minimum 60 calendar days before starting manufacture of any vehicle body structural parts.

2. Include a stress analysis of equipment supports for equipment weighing over 91 kg. Stress analyses for supports for items weighing less than 91 kg may be requested for review at the Engineer's discretion.

3. In addition to stress analysis, include the following:

   a. Detailed drawings of equipment supports.
   b. Outline drawings and weights of equipment.
   c. Material lists for all components and fasteners.

3-11 FEA Model:

1. Submit within 90 days after NTP.

2. The FEA Model shall be submitted and **approved** before **approval** of FEA analysis.

3. Include the following:

   a. Element mesh
   b. Assumptions
   c. Plots with legends showing input data such as loads, boundary conditions, area properties, and material properties
   d. Key to symbols and colors
   e. Boundary reaction forces of the shell at AW0
   f. Input file on electronic media

4. With each revision include detailed revision notes that explain each change and indicate where changes were made in the report as a result of the change.

5. Upon completion of final design, update FEA Model to represent final configuration of structure.

3-12 FEA Report:

1. Submit minimum 60 days before starting manufacture of any vehicle body structural parts.

2. Submit FEA Report after submitting the FEA Model and performing complete analysis.

3. In addition to the items required for this submittal, include those items required for the FEA Model submittal.

4. Upon completion of final design, update FEA Report to represent final configuration of structure.

5. Each load condition submittal shall include diagrams of areas of mesh refinement, assumptions, input data, reaction forces, and a table to show static equilibrium.

6. For input and output files, number each page and clearly label columns of data on each page using terms, symbols, abbreviations, and units defined in the analysis report.

7. Prepare color plots showing the following:

   a. Deflections in all three axes separately plotted and imposed over the deflected shape
   b. Von Mises, or other **approved** failure criteria, depending on the material
   c. Maximum and minimum principal stresses
   d. Direction of maximum and minimum principal stresses
   e. Meshing accuracy index
   f. Maximum and minimum values and values that are greater than 80% of specified maximum value.
   g. Triad showing direction of global axes.
   h. Close-up plots of all locations with stresses greater than 35% of the allowable limit for the load case.
   i. For plots at high magnification, key to a plot showing structure to an extent sufficient to orient high-magnification plots.

8. Furnish a sufficient number of plots for each load case to see the stresses in all areas of the vehicle body, with special attention given to the following components:

   a. Side sill
   b. Body sills (if used)
   c. End sill
   d. Anticlimber
   e. Draft sills
   f. Tow bar supports
   g. Coupler anchorage
   h. Side frame rails
   i. Side frame posts
   j. Transverse and longitudinal sections at doorway
   k. Body bolster
   l. Floor and floor beams
   m. Collision posts
   n. Corner posts
   o. Structural shelf
   p. Articulation end frame
   q. Roof structure
   r. Equipment supports
   s. Connections between structural elements

9. Show in detail areas with an MS less than 0.2.

3-13 FEA Input and Output Data on Electronic Media:

1. Submit FEA input and output data on electronic media, and if requested by the Engineer, hard copy.
2. Obtain **approval** for proposed media type before submitting.
3. Resubmit each time file is changed, but not more often than monthly.
4. Fully configured input data files shall be submitted before final **approval** of the stress analysis required by this Section.

3.8 Referenced Standards

The following standards are referenced in this Section:

ASME RT-1	Safety Standard for Structural Requirements for Light Rail Vehicles
AWS D1.1/D1.1M	Structural Welding Code - Steel
AWS D1.2/D1.2M	Structural Welding Code - Aluminum
AWS D1.3/D1.3M	Structural Welding Code - Sheet Steel
AWS D1.6/D1.6M	Structural Welding Code - Stainless Steel
AWS Welding Handbook	AWS Welding Handbook
EN 15227	Railway applications - Crashworthiness requirements for railway vehicle bodies

END OF SECTION

Table of Contents

4.1 General

4.1.1 Purpose

Provide a permanent, mechanical, tow bar styled coupling device at each end of every vehicle in order to allow one vehicle to tow and push another disabled vehicle. (See Section 2.7.17.2 Design and Performance Criteria, for specific towing or pushing requirements.)

4.1.2 Description

The coupling system shall be a manually operated, storable unit with resilient draft gear, compatible with those presently in use on similar vehicles for the same purpose.

4.1.3 Compatibility with Existing Vehicles

Streetcars shall be mechanically compatible with SEPTA's existing vehicle fleet for towing and pushing using a separate coupling system:

1. Mechanical interface between the Streetcar and existing LRVs shall occur between each anticlimber using a separate, existing tow bar in accordance with Section 3, Vehicle-Body Structure.

4.2 Geometry

The geometry shall comply with the following:

1. The coupling system shall permit vehicles to operate over track profiles specified in Section 2, Design and Performance Criteria, including the following conditions, without damage or stress outside the system design limits:
   a. Worst-case combination of horizontal and vertical curves, superelevation, track wear, and track misalignment.
   b. Variations between adjacent vehicles resulting from uneven loading, wheel wear, maximum suspension travel, and suspension failure.
2. Perform dynamic simulations, calculations, or both to demonstrate conformance to the design requirements. Simulations/calculations shall provide sufficient information and methodology to demonstrate that the Streetcar is capable of towing and or pushing without exception under the loaded conditions specified in this Section. Perform analyses for each of the following scenarios:
   1. Two Streetcars connected by a single tow bar
   2. A Streetcar connected to an existing single-ended LRV
   3. A Streetcar connected to an existing double-ended LRV

4.3 Mechanical Coupling

4.3.1 Coupling Device

Comply with the following for the tow bar:

1. Purpose:
    a. Acts as the connecting mechanism between two vehicles in the event of a disabled vehicle.
    b. Includes devices necessary to safely and securely lock coupling ends together between vehicle mating interfaces when coupled.
    c. Acts as a support structure for any electrical jumpers necessary to make trainlined connections such as communication, interior/exterior lights, brakes, etc.
2. Shape:
    a. Allows for vertical and lateral misalignment between tow bar ends.
    b. Allows self-alignment with the mating tow bar when the tow bars are brought together during a coupling operation.
3. Coupling:
    a. Manual coupling: Mechanism shall be engaged by inserting a pin, throwing a latch, or similar manual process.
4. Coupling with existing fleet for rescue operations:
    a. The Streetcar shall be able to be coupled mechanically via a tow bar to existing LRV fleet using a tow bar via pre-existing methods used on those vehicles as described in Section 4.1.3.

4.3.2 Strength

Comply with the following:

1. The tow bar, tow bar mechanisms, and draft gear shall be capable of withstanding buff or draft loads of not less than 133% (or tested to 110%) of the maximum forces experienced during coupling, towing, or pushing, with no permanent deformation.
2. The tow bar assembly strength shall be sufficient to meet the towing requirements and operational requirements specified in Section 2, Design and Performance Criteria.
3. See Section 3, Vehicle-Body Structure, for tow bar anchor requirements.

4.3.3 Draft Gear and Anchorage

Comply with the following:

1. Draft gear:
    a. Cushioning: Provide in both buff and draft

b. Resilient mounting: Provide in the vertical direction to maintain nominal coupling height above top of rail.

2. Supporting device at coupling anchor point:

   a. Shall maintain tow bar and draft gear assembly at the specified coupling height above top of rail.

   b. Shall allow a means of vertical height adjustment of the tow bar head to compensate for vehicle and coupling variations, failure, and wear.

3. Tow bar assembly mounting: Shall be bolted to the vehicle structure under the cab floor. See also Section 3, Vehicle-Body Structure.

4.3.4 Tow Bar Storage

When not in use, the tow bar shall fold or retract under the vehicle behind a removable or hinged cover, as specified in Section 3, Vehicle-Body Structure:

1. Operation: The storage mechanism shall permit a maintainer to manually deploy and stow the tow bar with minimal physical effort.

2. Operating position lock:

   a. Provide a device to lock the tow bar into its operating position, and to release the tow bar for storage.

   b. The device may be integral to the tow bar mechanism, or a separate device. If separate, it shall be stowed on the tow bar.

3. Stowed position lock:

   a. Provide a device or other **approved** means to lock the tow bar assembly into its stowed position, and to release the tow bar for operation.

   b. The tow bar assembly shall be retained rigidly to prevent noise and vibration or other unwanted movement, either during vehicle operation or otherwise.

4. During tow bar deployment or stowage, the removable or hinged cover:

   a. Shall be conveniently stored in an easily accessible location

   b. Shall not interfere with the tow bar, anticlimber, or any other dynamic components.

   c. Shall be secure against noise and vibration or other unwanted movement, both during vehicle operation and otherwise.

5. During tow bar deployment, the removable or hinged cover shall be stored or locked as to not interfere with a lone maintainer’s ability to manipulate the tow bar.

6. The removable or hinged cover shall meet the impact and strength requirements of Section 3, Vehicle-Body Structure.

7. The removable or hinged cover shall include a seal to prevent the ingress of water and other debris into the stowage compartment.

8. Provide an **approved** locking mechanism (such as a “church key” or “T key”) to limit access to the tow bar to authorized personnel.

4.4 Electrical Connections

Provide a connector, wiring, and related hardware for a temporary electrical connection for communication between vehicle cabs, as specified in Section 13, Vehicle Communication Systems:

1. The connection shall be made manually.

2. The arrangement shall allow for all tow bar motions without damage to connectors or wiring.

3. The electrical connector cable assembly shall be easily replaceable and shall not require the disassembly of any major components.

4. The connectors and wiring system shall be watertight and meet the multi-pin connector requirements of Section 16, Materials and Workmanship.

5. Provide a watertight cap to protect the connector when not in use. The cap shall be retained by chain, lanyard, or similar device when not applied.

4.5 Towing and Pushing Under Emergency Conditions

Comply with the following:

1. Determine and specify a maximum speed for towing/pushing a disabled vehicle. If it is determined that this governing speed is less than normal operating speeds, provide an interlock with the propulsion system to ensure that no vehicle is operating above such speed when the tow bar is in use. Such restrictions shall be indicated on the cab display and logged in the MDS.

2. The tow bar and draft gear(s) shall allow a powered train to couple to and tow or push an inoperable train between stations over any section of the alignment without damage to the tow bars, other components, or vehicle structures under the following conditions:

    a. Powered train: One-vehicle train with an AW3 passenger load operating at degraded dynamic performance, including any brake rates possible under such conditions

    b. Inoperable train: Maximum one vehicle with an AW3 passenger load

    c. Alignment: All grades and curves on the system as defined in Section 2, Design and Performance Criteria

3. Existing Fleet:

    a. Coupling with mixed fleet vehicles shall meet the requirements specified in this Section.

4.6 Contract Deliverables Requirements List (CDRL)

4-1 Tow Bar Design Package

4.7 CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, existing fleet coupler assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested
5. Software functional descriptions: Include top level control parameters and values

4-1 Tow Bar Design Package:

1. Operating Description: Narrative describing how to deploy, couple, uncouple, and store tow bar assembly.
2. General Arrangement Drawings: Show tow bar components with dimensions
3. Detail Drawings: Include details of the draft gear, folding or storing mechanism, hinged or removable storage cover, coupling head, and latching mechanism.
4. Material Properties:
    a. Indicate the material used for each component, unless indicated on Detail Drawings.
    b. Furnish data on properties of each material used.
    c. Include treatments, coatings, lubrication requirements, and similar data.
5. Strength Analysis:
    a. Furnish sufficient information to demonstrate that the specified strength requirements have been met.
    b. If available, manufacturer’s test data may be used for this purpose.
6. Towing Analysis:
    a. Furnish sufficient information to demonstrate that the specified towing requirements have been met.
    b. If available, manufacturer’s test data may be used for this purpose.
7. Electrical Connections:
    a. Detail drawings with manufacturer’s part numbers for standard parts.

b. Include connector material and certification details.

4.8 Referenced Standards

There are no standards referenced in this Section.

END OF SECTION

Table of Contents

Table of Tables

5.1 General

5.1.1 Scope

This Section includes controls located in or originating from the Operator's cab at each end of the vehicle. The cab area shall contain all controls, displays, and appurtenances necessary for normal and abnormal vehicle operation.

Design and furnish the cab as specified in Section 14, Interior and Exterior Appointments.

5.1.2 Controls and Indicators

Comply with the following:

1. Locate all controls and indicators necessary for vehicle operation in the cab.
2. Provide status and fault indicators for major systems.
3. Provide specified controls and indicators in both cabs; cabs shall be identical.

5.2 Cab Console

5.2.1 Cab Console Design

Design Cab Console such that Operator has good visibility of controls and labels. For Cab Console design and materials, see Section 14, Interior and Exterior Appointments.

5.2.2 Cab Console Layout

Comply with the following:

1. Unless otherwise specified or permitted in the Contract Documents, locate controls and indicators on the Cab Console directly in front of the Operator's seat.
2. Arrange controls in an ergonomic manner based on the following:
    a. Relative frequency and criticality of each task
    b. Size range of Operators as specified in Section 14
    c. Design principles of the following:
        - *The Measure of Man and Woman: Human Factors in Design*
        - MIL-HDBK-759
        - SAE J287
        - SAE J1050
        - SAE J1139
        - SAE J1517
        - SAE J1522
    d. Location that minimizes reach and reduces Operator strain and fatigue

3. Design to avoid unintentional activation.

5.3 Master Controller Group

5.3.1 General

The Master Controller (MC) group consists of a MC key switch, Reverser switch, and MC. Alternative arrangements with functionality similar to that described below may be considered by the Engineer.

5.3.2 Master Controller Key Switch

Provide a two-position MC key switch to select cab status:

1. Mechanically interlock the MC key switch with the MC and Reverser switch, as described in the Reverser Switch and Master Controller sections, below.

2. Provide the following functionality:

    a. MC key switch keyed to On position:

    - The cab is active. The Cab Console, other cab controls and displays, hotel load systems, and all other vehicle systems activate and function in their normal operating modes.
    - Systems already energized remain energized without interruption.
    - Doors remain in last commanded state (OPEN, CLOSED, or ENABLED)
    - Cab Console controls and indicators in all other cabs are disabled, except as specified otherwise.
    - The MC key shall not be removable in this position.
    - Keying On more than one MC key switch in a train shall be detected by software and considered an invalid command, and the additional cab shall not be activated. Annunciate the attempt to activate an additional cab on the TOD in the active cab.

    b. MC key switch keyed to Off position (all cabs OFF):

    - Hotel Load timer activates (see description of operation below).
    - The Cab Console and other cab controls de-activate and are non-functional, except the following remain active:
        - Battery charging
        - Other systems specified to be active at all times
        - Systems maintained by the Hotel Load timer
    - Doors remain in the last commanded state (OPEN, CLOSED, or ENABLED)
    - The MC key shall be removable in this switch position.

3. Additional MC key switch and cab interlock controls are detailed within this Section.

5.3.3 Reverser Switch

Provide a three-position Reverser switch with these positions: Forward, Neutral, Reverse.

1. Mechanically interlock MC key switch and Reverser switch as follows:
    a. Reverser switch cannot be moved from Neutral position unless associated MC key switch is in On position; and
    b. MC key switch cannot be moved from On position unless Reverser switch is in Neutral position.
2. Electrical Interlocking:
    a. Vehicle operation shall not be possible unless Reverser switch in controlling cab is in either Forward or Reverse position;
    b. Reverser switch and MC: MC handle must be in FSB position in order to move Reverser switch out of either Forward or Reverse position;
    c. Initiate FSB if forward and reverse commands are given simultaneously, record error state by MDS, and indicate error on TOD.

5.3.4 Master Controller

5.3.4.1 General

Provide a MC to allow manual selection of braking and motoring efforts. The MC shall be arranged to move linearly fore and aft, with motoring in the forward direction and braking towards the rear (that is, towards the Operator).

5.3.4.2 Ergonomics

The handle shall be shaped, located, and oriented to minimize strain and fatigue on the Operator. Locate the MC for left hand operation.

5.3.4.3 Handle Positions

There shall be distinct tactile positions in the handle travel, indicated by stops or detents, as indicated below:

TABLE 5-1, MASTER CONTROLLER HANDLE POSITIONS		
Function	**Position/Tactile Indication**	**Rate**
Maximum Brake (MB):	Stop (rearmost position)	See Section 2
Full Service Brake (FSB):	Detent	See Section 2
Minimum Brake:	Slight Stop	Approximately 10% of FSB
Coast:	Detent	
Minimum Power:	Slight Stop	Approximately 10% of Max Power
Maximum Power:	Stop (forward-most position)	See Section 2

Notes to Table:

1. Between Maximum Power and Full Service Brake, braking and power efforts shall be linearly proportional to handle position.
2. The MC shall stow in the FSB position when the cab is inactive.

5.3.4.4 Deadman

The MC handle shall incorporate a deadman feature with associated circuitry:

1. Deadman shall perform as follows:
   a. Release of the deadman at any MC position other than FSB or MB:
      - Initiate an audible alarm.
      - After a two-second time delay apply FSB.

   b. If deadman is picked up during the alarm and before FSB is initiated, the dead man timer shall be reset, and the alarm cancelled.

   c. Once a deadman-initiated FSB is applied, FSB will remain applied and cannot be released by the MC until the vehicle has achieved no-motion and the MC is placed into a FSB or MB position.

   d. MC handle in FSB or MB position: Deadman function shall be disabled.
2. The circuit and timing function shall be a safe function as defined in Section 2, Design and Performance Criteria.

5.4 Cab Console Switches

5.4.1 General

Comply with the following requirements for switches:

1. Type: Heavy-duty industrial grade, IP66 rated in conformance with IEC 60529.

2. Illuminated Type: Backlighted by LEDs.

3. Identification: Provide a durable and permanent label for each control switch.

4. Quality:

    a. All switches provided shall be of the highest quality procurable and shall be fully suitable for the rigors of a railroad service environment.

    b. All control switches that are subject to environmental factors such as water splash and driving rain shall be environmentally sealed. This includes switches mounted near windows or doors, or mounted on the Cab Console.

5.4.2 Summary of Control Functions with Basic Switch Types

Provide control functions on the Cab Console as shown in the following table. Typical switch and control types are presented, although the Contractor may propose alternate designs, including via TOD touch screen, if similar functionality is provided.

Additional control functions with special requirements are described separately.

TABLE 5-2, SUMMARY OF CONTROL FUNCTIONS WITH BASIC SWITCH TYPES

Control Function	Type Code (see key below)
Master Controller Group	See Master Controller Group section, above
Left Door Close	MPB (illuminates green); Notes 3, 4
Left Door Open	MPB (illuminates red); Notes 3, 4
Left Door Enable	MPB (illuminates yellow); Notes 3, 4
Right Door Close	MPB (illuminates green); Notes 3, 4
Right Door Open	MPB (illuminates red); Notes 3, 4
Right Door Enable	MPB (illuminates yellow); Notes 3, 4
Right Door Cab Adjacent Open	MPB (illuminates green); Notes 3, 4
Right Door Cab Adjacent Close	MPB (illuminates red); Notes 3, 4
Left Door Cab Adjacent Open	MPB (illuminates green); Notes 3, 4
Left Door Cab Adjacent Close	MPB (illuminates red); Notes 3, 4
Wiper, Off/Intermittent/Low/High	4R
Wiper Delay Adjust	Rotary Potentiometer
Windshield Washer, On/Off	MPB; Note 3

TABLE 5-2, SUMMARY OF CONTROL FUNCTIONS WITH BASIC SWITCH TYPES	
Control Function	**Type Code (see key below)**
Headlight, High/Low	LPB (illuminates for high beams); Notes 2, 3, 4
Turn Signal, Left/Off/Right	3MTRC
Hazard Lights, On/Off	LPB (illuminates yellow); Notes 2, 3, 4
Cab Ceiling Light (general Illumination) On/Off	LPB; Notes 2, 3
Cab Ceiling Light, dimmer	Rotary dimming control; Note 1
Cab-Console-Mounted Light, dimmer	Rotary dimming control; Note 1
Cab Console Indicators, dimmer	Rotary dimming control; Note 1
Indicator Lamp Test	MPB; Notes 3, 5
Horn, On/Off (automobile warning)	MPB; Note 3
Bell, Low/Off/High (pedestrian warning)	3MTRC
PA	MPB; Note 3
Cab-to-Cab Intercom	MPB; Note 3
Passenger Emergency Intercom acknowledge/pick up call on hold	MPB; Note 3
Windshield Heating (embedded heater)	LPB; Notes 2, 3
Cab Heater Off/Fan/Low Heat/High Heat	4R
CBTC Mode Switch	Rotary switch; see Section 21
CBTC Alerter Switch	See Section 21
CBTC RM Release Switch	See Section 21
Track Brake, On/Off	MPB; Note 3
Emergency Brake	See switch description below
Manual Sander, On/Off	MPB or momentary toggle; Note 3
HSCB (Propulsion) Reset	3MTRC
Pantograph Up/Down	3MTRC
Auxiliaries On/Off	See switch description below
TWC Control Module	See Section 13
Regenerative Brake Cutout	2R, sealable cover
Vehicle Wash Mode	2R

TYPE CODE KEY FOR TABLE 5-2	
LPB	Pushbutton with latching circuitry (push on, push off)
MPB	Momentary pushbutton
3MTRC	Three-position momentary toggle switch, spring return to center
2R	Two-position rotary
3R	Three-position rotary
4R	Four-position rotary
Rotary Potentiometer	Continuously adjustable control

Notes to Tables Above:

1. Dimming control: See Section 8, Lighting, Power Source and Control section.
2. Latching: Provide the indicated latching functions using electrical circuitry or software. Mechanically latching switches are prohibited, with the exception of the emergency brake switch described below. No railroad headlight
3. Review track brake switch function.
4. Pushbutton switches: Shall be flush or recessed to prevent inadvertent operation.
5. Illuminated switches: Shall show the state of the controlled circuit, not the state of the switch.
6. Indicator Lamp Test: Shall illuminate all discrete indicators on the console.

5.4.3 Emergency Brake Switch

Comply with the following:

1. Type: Heavy duty, industrial grade self-latching pushbutton gang switch with a large, red mushroom-shaped twist-to-unlatch actuating head.
2. Location: Cab Console in each cab.
3. Configuration: The switch mechanism shall be arranged with two switches for the main emergency brake circuits, with a switch contact in each of the positive and negative portions of the circuits.
4. Strength: The actuation mechanism shall be sufficiently robust such that striking the mushroom head will ensure breaking the circuit even with welded contacts.
5. Function: Switch and circuits are powered only from the active cab (MC key switch ON). With an active cab, switch shall be functional in all cabs. With no active cab, the switch and circuits shall be de-energized and the switch non-functional. See additional control requirements below.
6. Release: Twist to unlatch an activated (latched) EB pushbutton.

7. Circuits: The active cab shall energize the only power and return circuits for control of all emergency brake equipment in the vehicle.

8. See Section 2, Design and Performance Criteria, for additional emergency brake requirements.

5.4.4 Special Switch-Layout Requirements

Comply with the following layout requirements for specific switches:

1. Passenger Doors: Position controls for safe actuation, with the right-side door controls on the right side of the Cab Console, and the left-side door controls on the left side of the Cab Console.

2. Pantograph Up/Down: Locate near HSCB reset and away from commonly used controls.

3. CBTC Alerter Switch: Locate in an ergonomic location for Operator to frequently trigger.

4. CBTC RM Release Switch: Locate in an ergonomic location for Operator to be able to reach from seated position, but not trigger inadvertently.

5.5 Cab Console Indication and Annunciation

Comply with the following requirements for indicators:

1. Type: LED, heavy-duty industrial grade devices, IP66 rated in conformance with IEC 60529.

2. Activation: Indicators shall illuminate only in the active cab.

3. Identification: Provide a durable and permanent label for each indicator, on the indicator itself, wherever possible.

4. Provide indications in the cab as shown in the table below. Indicating switches (illuminate to show state of circuit) are shown above in the Cab Console Switches section:

TABLE 5-3, CAB CONSOLE INDICATION AND ANNUNCIATION		
Indication/Annunciation	**Symbol/ Action**	**Activation Description**
Left turn signal	Left-facing arrow/ flashing	Flashes when corresponding turn signal is active
Right turn signal	Right facing arrow/ flashing	Flashes when corresponding turn signal is active
Odometer		See below
Passenger Stop Request	Visual and audible	See Sect 6
Interior Manual Door Release (Passenger Emergency Switch)		See Sect 6
Door Open or Unlocked		See Sect 6
Door Cutout		See Sect 6
Overhead Heat high-limit temperature indication		See Sect 7
Tripped or Open HSCB		See Sect 9
ADU		See Sect 13
Electronically Coupled (TL)	Visual	Illuminated when turn signals, interior/exterior lights, PA, etc. are connected via trainline
Shop Power	Visual	Illuminated when shop power is connected to the vehicle
Track Brake	Visual and audible	Illuminated and activated when track brake is activated manually or automatically
Snow Brake	Visual	Illuminated when Snow Brake switch is energized
Sanding	Visual	Illuminated when sand is being applied

Notes to Table:

1. Some of these annunciations may be part of the TOD, if **approved**.

5.6 Other Displays and Control Groups on the Cab Console

5.6.1 MDS Train Operator Display(s) (TOD)

The MDS TOD(s) shall be part of the Monitoring and Diagnostic System (MDS) specified in Section 17, Controls, Networks, and MDS. See Section 17 for TOD display and control requirements.

Provide one or more MDS TOD(s) in the cab complying with the following requirements:

1. Location: Near the center of the Cab Console, in a location free of glare and reflections under all natural and artificial lighting conditions.
2. Purpose: Display information useful to the Operator when the vehicle is in motion or during a normal station stop, including all vehicle status indications. Provide vehicle control functions, as **approved**, via the touch screen interface.
3. Odometer: The propulsion system shall transmit distance traveled information to the MDS that will display the odometer mileage on a dedicated display. An alternative source for the distance traveled information to be reported to the odometer may be presented during design review.
4. Brake Cylinder and Emergency Brake Pressure Gauge: The friction brake system shall transmit cylinder pressure information to the MDS, which shall display the pressure for both the friction brake and the emergency brake on a dedicated duplex-style display.

5.6.2 CBTC Train Operator Display (TOD)

The TOD shall be part of the Communications-Based Train Control System (CBTC) specified in Section 21, Communications Based Train Control. See Section 21 for TOD display and control requirements.

Provide a TOD in the cab complying with the following requirements:

1. Location: Near the center of the Cab Console, in a location free of glare and reflections under all natural and artificial lighting conditions.
2. Purpose: Display information useful to the Operator when the vehicle is in motion or during a normal station stop, including all CBTC indications. Provide vehicle control functions, as **approved**, via the touch screen interface.

5.6.3 Interior View CCTV Display Screen

Provide a system of cameras and display screen for viewing the passenger compartment to replace the view from a cab interior mirror:

1. Camera:
   a. Type: Comply with requirements for CCTV cameras. See Section 13, Vehicle Communication Systems.
   b. Locations: In the passenger compartment, aimed to view down the center of the vehicle.
   c. Interior mirror. See section 14
2. Display:
   a. Type: See Section 13.
   b. Location: On upper cab console, adjacent to the cab mirror, positioned so as not to obstruct the Operator's field of view through the windshield.

c. Activation: When cab is active.

5.6.4 Exterior Side-View CCTV Display Screens

Provide two display screens in each cab for viewing the exterior sides of the vehicle, as specified in Section 13:

1. Mount displays on the right and left sides of the Cab Console or on the corner posts.

2. Arrange displays to be viewed easily regardless of whether the Operator is seated or standing.

5.6.5 Automatic Vehicle Location (AVL) Mobile Data Terminal (MDT)

Provide one AVL MDT in each cab to address the requirements for the Automatic Vehicle Location system in Section 13, Vehicle Communications.

5.6.6 TWC Control Panel

Provide one TWC control and indications panel to address the requirements for the TWC system in Section 13, Vehicle Communication Systems.

5.6.7 Discrete Indicator Group

Comply with the following:

1. Provide minimum 12 LED indicators that duplicate selected status indications shown on the TOD. Indicators shall give sufficient information to Operator to allow safe operation of vehicle in service with a non-functioning TOD.

2. At a minimum, the group shall continuously display the following indications, with the balance of the indicators subject to **approval**:

   a. Door Closed indication

   b. Brake Released indication

   c. Bypass Active indication

   d. Friction Brake Fault indication

   e. Radio and Communications Group

   f. Traffic Light Priority status indication

   g. Collision Avoidance System Health Status

   h. Collision Avoidance System Penalty Brake Activation Status

   i. Towing Trainline indication

3. Comply with the following, and see Section 13, Vehicle Communication Systems for additional requirements:

   a. Furnish and install radio equipment as per SEPTA specifications.

b. Locate audio and radio system control heads on right side of Cab Console, close enough to allow easy access for the Operator. Arrangement shall permit safe operation of the vehicle with the Operator's left hand on the MC.

c. Automatic Passenger Information System (APIS) Control Panel:

- Provide a separate APIS Control Panel to the right of audio and radio system control heads to control automatic destination signs and announcements.
- APIS control may be incorporated into the CAD/AVL MDT with **approval**.

5.6.8 Train-to-Wayside Communications (TWC) Group

Provide a TWC Cab Control Panel in each cab, as specified in Section 13, Vehicle Communication Systems.

TWC status information shall also be shown on the Operating Status Screen of the TOD.

5.6.9 Overspeed Alarm

Provide an audible alarm and a visual indicator for over-speed indication. Speedometer shall have a range of 0 to 50 MPH.

5.7 Cab Console Functional Descriptions

5.7.1 Scope

This Section includes specific functionality that originates in the cab. Other cab functionality, and functional descriptions for systems that require a response from the Operator, such as passenger emergency intercom and passenger stop request, are described in other sections of the Specifications.

5.7.2 Door Controls

Comply with the following:

1. Door Open:

   a. Pressing the Door Open pushbutton shall open all doors on the selected vehicle side.

   b. Doors shall remain open until the Door Close pushbutton is pressed.

2. Door Enable:

   a. Pressing the Door Enable pushbutton for the doors on a given side of the vehicle shall enable the local door pushbuttons on the inside and outside of the vehicle on the selected side.

3. Door Close:

   a. Pressing the Door Close pushbutton shall close all doors on the selected vehicle side, including doors opened by a crew door-switch and doors fixed open by the obstruction detection counter.

b. The Door Close command shall cancel Door Enable and Door Open commands.

c. The Door Close command shall cancel passenger stop request.

4. Adjacent Door:

a. Pressing the Adjacent Door pushbutton shall open or close the door adjacent to the switch. Specific controls and functionality will be determined during concept of operations definition and furthered in cab and door design reviews.

5. Bridge Plate Deployment: Door system shall have the option to have the Bridge Plate Extend command open all doors on the selected side of the vehicle. The option shall be user selectable using a PTU connected to each associated door control unit.

5.7.3 Bridge Plate Controls

Comply with the following:

1. Door Open:

a. Pressing the Door Open pushbutton shall enable the local bridge plate pushbuttons on the inside and outside of the vehicle on the selected side.

b. If a passenger bridge plate request has been stored within the system, pressing the Door Open pushbutton shall cause the actions described in 4 b, below.

2. Door Enable:

a. Pressing the Door Enable pushbutton for the doors on a given side of the vehicle shall enable the local bridge plate pushbuttons on the inside and outside of the vehicle, on the selected side.

b. If a passenger bridge plate request has been stored within the system, pressing the Door Enable pushbutton shall cause the actions described in 4 b, below.

3. Door Close:

a. Pressing the Door Close pushbutton shall close the door and retract the bridge plate on selected side of vehicle.

b. The Door Close command shall cancel passenger bridge plate request.

c. Upon successful closing, the bridge plate obstruction detection shall be disabled.

4. Bridge Plate Retract/Extend: Pressing a Bridge Plate Retract/Extend pushbutton will have different consequences depending upon positions of the doors and bridge plate. The following actions will occur in the sequence listed with the positions stated:

a. Door open and bridge plate retracted:

- Door closing warning
- Close doors
- Start interior and exterior bridge plate movement audible warning

- Extend bridge plate
- Stop interior and exterior bridge plate movement audible warning
- Open doors

b. Door closed and bridge plate retracted:

- Keep door with bridge plate request closed
- Start interior and exterior bridge plate movement audible warning
- Extend bridge plate
- Stop interior and exterior bridge plate movement audible warning
- Open door

c. Door open and bridge plate extended:

- Close door
- Start interior and exterior bridge plate movement audible warning
- Retract bridge plate
- Stop interior and exterior bridge plate movement audible warning
- Cancel passenger bridge plate request

d. All other system combinations shall alert the Operator of a system fault.

5.7.4 Public Address (PA) System

Comply with the following:

1. The Operator shall be able to select where Operator PA announcements are broadcast via the AVL MDT:

   a. Interior of the vehicle only

   b. Exterior of the vehicle only

   c. Both interior and exterior

2. Operator-initiated PA messages shall override passenger information system and door system messages.

3. Control center to be able to speak directly to the car.

5.7.5 Cab-to-Cab Intercom

Provide controls on the Cab Console for the cab-to-cab intercom as specified in Section 13, Vehicle Communications Systems.

5.7.6 Initiation of Automatic Passenger Information System (APIS) Announcements

Comply with the following:

1. APIS announcements shall be initiated by the Operator entering a route ID number into the CAD/AVL MDT, which shall determine which message sequence and special features are to be used by the system.

2. The present location of the vehicle in the route's station sequence may also be entered if vehicle location is not known at initiation.

3. Once initiated, the system shall be automatic, as specified in Section 13, Vehicle Communication Systems.

4. System initiation shall also establish the settings for the end destination signs in each cab and side destination signs in the vehicle.

5. The system shall give a positive indication to the Operator when all signs in the vehicle have the proper display. As required under abnormal or emergency vehicle operation, this shall apply across electrically coupled vehicles.

5.8 Other Cab Controls

5.8.1 General

Comply with the general requirements for Cab Console switches and indicators in the Cab Console Switches section, above.

5.8.2 Bypass Panel

5.8.2.1 General

Provide a Bypass Panel mounted outside reach of a seated Operator.

5.8.2.2 Switches

At a minimum, include the following switches, bypass controls, and switch types in the Bypass Panel:

TABLE 5-4, BYPASS PANEL	
Control	**Type**
Audible Alert Bypass	2R, sealed
No Motion Bypass	2R, sealed
Door Interlock Bypass	2R, sealed
CBTC Bypass	Sealed; see Section 21
CBTC Towing Mode	Sealed; see Section 21
Collision Avoidance System Bypass	2R, sealed
Traffic Light Priority Bypass	2R, sealed
Friction Brake Applied Bypass	2R, sealed

TYPE CODE KEY FOR TABLE 5-4	
2R	Two position rotary (recommended, but another switch type may be substituted subject to **approval**)
3R	Three position rotary (recommended, but another switch type may be substituted subject to **approval**)

5.8.2.3 Functional Description

Bypass shall function as described below:

1. Seal: Breakable by the Operator without the need for tools.
2. Bypass status and indication:
   a. Bypass status and indication shall appear in the active cab and MDS TOD regardless of location of bypass in the vehicle or train. CBTC bypass shall also be shown on CBTC on CBTC TOD.
   b. Bypass Active shall illuminate if any bypass switch is activated, and shall flash if more than one bypass is active.
3. Activated Bypasses:
   a. Bypass shall function regardless of cab active status, except CBTC Bypass and CBTC Towing Mode (see CBTC Controls section, below).
   b. Each bypass applies to the entire vehicle and train, regardless of which cab is active.
4. Bypass Reset: Each bypass shall be individually resettable regardless of cab status.

5. Bypass Record: Each bypass action, including reset, shall be recorded in the event recorder and VCU.

5.8.2.4 Individual Bypass Functional Description

The sealed bypass switches listed above shall function as described below:

1. Audible Alert Bypass: Acknowledges and cancels the following audible alarms:
    a. Emergency door operating device activated
    b. Friction brake or dynamic brake fault
2. No-Motion Bypass: This switch shall bypass the local no-motion detection circuits, which prevent door operation.
3. Door Interlock Bypass: This switch shall bypass the summary door interlock circuit, which prevents propulsion in the event of an open door (see also Section 6, Passenger Doors).
4. CBTC Bypass: See Section 21, Communications Based Train Control.
5. CBTC Towing Mode: See CBTC Controls section, below, and Section 21.
6. Collision Avoidance System Bypass: This switch shall disable the collision avoidance system specified in Section 21.
7. Traffic Light Priority Bypass: This switch shall disable traffic light priority on the vehicle.
8. Friction brake applied bypass: Allows propulsion to move the vehicle when there is a brake applied indication.

5.8.3 Not Used

5.8.4 Hotel Load Timer

Provide a user-programmable timer that controls hotel load systems and functions in conjunction with the Auxiliary On/Off switch, below:

1. Enabled: Only when no cab is active.
2. Activated: Whenever MC key switch is switched Off, or if Auxiliary On/Off switch is switched to On.
3. Hotel load systems: HVAC, cab heat, interior lights, exterior lights, passenger door controls.
4. Timer setting: Adjustable from 1 to 120 minutes in 1-minute increments, initially set to 30 minutes.

5. Function:

   a. Upon activation:

      - Resets timer to full set value, and turns On all hotel load systems, into their normal operating states.
      - If hotel load systems are already ON when the timer is activated, maintains those systems in their ON state without interruption.

   b. End of the timer setting: Shuts down hotel load systems and activates HVAC layover mode, as specified in Section 7, Heating, Ventilating, and Air Conditioning.

   c. Delayed Off: When Auxiliary On/Off switch is placed in Off position, and the Hotel Load timer has not expired, set the timer for 1 minute. The Delayed Off time setting shall be user settable to any value less than the timer setting, including zero. For battery load control using the Delayed Off timer, see Section 9, Electrical Equipment.

6. See Battery Load Control section in Section 9, Electrical Equipment, for related requirements.

5.8.5 Auxiliary On/Off Switch

Provide an Auxiliary On/Off switch in each cab that functions in conjunction with the Hotel Load timer, above:

1. Type: Momentary, three-position, return to neutral center. Alternate arrangement is acceptable if **approved**.

2. Enabled: Only when there are no active cabs.

3. Function:

   a. On position: Activates the Hotel Load timer.

   b. Off position:

      - Sets the Hotel Load timer to the Delayed Off setting.
      - Coordinate between Auxiliary Off command and other vehicle systems as necessary for HVAC shut down procedures.

   c. Activating a cab shall return auxiliaries control to the active cab.

4. Exterior Auxiliary On function: See Crew Door-Switch section in Section 6, Passenger Doors.

5.8.6 Cab HVAC Unit Controls

Provide a temperature controller:

1. Type: Digital, as provided by the HVAC supplier

2. Location: Controls shall be accessible to Operator in ergonomic location from Operator seat.

5.8.7 Sander Control

Comply with the following:

1. Automatic: System shall apply sand in response to emergency brake applications and spin/slide activities, in accordance with the braking requirements in Section 2, Design and Performance Criteria, and Section 12, Friction Brake System.

2. Manual:

    a. System shall apply sand in response to operation of the Manual Sander switch by the Operator.

    b. Manual operation of the sanders via the switch shall not be canceled below the no-motion detection point.

5.8.8 Silent Alarm Button

Provide a hidden silent alarm button in the cab as part of the AVL system. See Section 13, Vehicle Communication Systems, for requirements.

5.8.9 Vehicle Wash Mode

Provide a switch for activating and deactivating Vehicle Wash Mode. Vehicle Wash Mode shall limit the vehicle's speed and de-energize ventilation fans to limit ingress of water as per Section 7, Heating, Ventilating, and Air Conditioning, and Section 10, Propulsion System and Control.

5.8.10 Cleaning mode.

Provide sufficient lighting with vehicle in cleaning mode.

5.9 Automatic Controls

5.9.1 Interior Lighting Control

Comply with the following functional requirements:

1. Cab-Console-mounted light: Shall be ON when the Cab Console is powered.

2. Cab Console indicators: Shall be ON when the Cab Console is powered.

3. Passenger compartment lighting: Shall be ON whenever either cab is ON. It shall remain active with both cabs OFF when controlled by the Hotel Load timer or the Auxiliary On/Off switch as described above.

5.9.2 Exterior Lighting Control

Comply with the following functional requirements:

1. With a cab active and Reverser switch in Neutral:
    a. Red marker lights at both ends of train or single vehicle are illuminated
    b. Amber marker lights on sides of train or single vehicle are illuminated
    c. Taillights on front and rear ends of train or single vehicle are illuminated
2. With a cab active, Reverser Switch in Forward or Reverse, as determined by the forward and reverse directional control lines:
    a. Amber marker lights on the front end of train or single vehicle only are illuminated
    b. Red marker lights on the rear end of train or single vehicle only are illuminated
    c. Amber marker lights on front sides and midpoint of train or single vehicle only are illuminated
    d. Red marker lights on rear sides of train or single vehicle only are illuminated
    e. Headlights only at the front of train or single vehicle are illuminated
    f. Taillights only at rear of train or single vehicle are illuminated
3. Stop lights shall be illuminated at the rear of the vehicle whenever a direction has been selected and any brake mode has been selected, including manual track brake application.
4. The headlights shall flash alternately when the Operator's cab horn is sounded. The flashing rate shall be adjustable from 40 to 180 flashes per minute and shall initially be set to flash alternately at 60 flashes per minute.

5.9.3 HVAC Control

Provide HVAC control as follows:

1. Passenger compartment:
    a. HVAC system shall activate automatically whenever the MC key switch in any cab in a vehicle or train is placed in On position.
    b. HVAC system shall remain active when both cabs are OFF until the Hotel Load timer expires or when activated by the HVAC layover mode circuitry (see Section 7, Heating, Ventilating, and Air Conditioning).
2. Operator's cab:
    a. Cab air comfort controls shall activate automatically when a Cab Console is activated and deactivate after a time delay when the Cab Console is deactivated. See Hotel Load timer section, above.

b. Cab HVAC shall maintain temperature automatically when in HVAC Layover mode or in an inactive cab as described in Section 7.

5.9.4 Parking Brake Control

Parking brake shall be applied automatically when Reversers in each cab are all in the Neutral position and when more than one reverser in a train is not in the Neutral position. For additional control requirements, see Section 12, Friction Brake System.

5.10 Control Configurations and Interlocks

5.10.1 General

Control of the vehicle shall be via Train Communication Network (TCN) signals, as specified in Section 17, Controls, Networks, and MDS.

1. Implement vehicle control schemes as specified below.
2. Control of cab systems not described below or in other sections shall be determined by the Contractor.
3. Unless otherwise indicated in the Contract Documents or **approved**, all control signals, interlocks, and other vehicle controls shall operate from the low-voltage power supply.

5.10.2 Cab Interlock

Interlock cab controls using control lines and associated circuitry such that no more than one cab can take control of a vehicle at the same time.

1. Interlocking shall be accomplished by relay logic.
2. Interlocking that depends on mechanical locking of transfer switches with electrical solenoids is prohibited.

5.10.3 Direction Control

Direction signals shall be given by a pair of control lines, designated Forward and Reverse:

1. Direction signals shall originate at the controlling cab's Reverser switch.
2. Arrange associated circuitry such that one control line must be energized while the other must be de-energized for correct operation.
3. Energization or de-energization of both control lines at the same time shall inhibit propulsion and display a fault on the MDS TOD.

5.10.4 Track Brake Control

Provide a track brake switch for Operator control of track braking:

1. Location: Cab Console in each cab.

2. Switch type: See switch requirements above.
3. Control configuration: See Section 12, Friction Brake System.
4. Switch function:
    a. Shall activate all track brakes on the vehicle.
    b. Shall not be canceled below the minimum track brake speed as specified in Emergency Brake section of Section 2, Design and Performance Criteria.
    c. Shall not inhibit propulsion.

5.10.5 Hazard Lights

Provide a hazard light switch to cause turn signals to function as hazard lights:

1. Location: Cab Console in each cab.
2. Switch type: See switch requirements in Summary of Control Functions with Basic Switch Types section, above.
3. Activation: Switch shall be enabled at all times in all cabs.
4. Function:
    a. Switch activated: All turn signals in the vehicle flash.
    b. Deactivation: Lights shall remain flashing until switch is turned Off, regardless of cab activation.

Hazard light indicator: Illuminates and flashes only in the cab with the activated switch.

5.10.6 CBTC Controls

Comply with the following:

1. Provide a CBTC Mode switch to meet the requirements specified in Section 21, Communications Based Train Control:
    a. Location: Cab Console in each cab.
    b. Switch type: See switch requirements in Summary of Control Functions with Basic Switch Types section, above, and in Section 21.
    c. Function:
        - Automatic Train Protection Mode (ATPM): Automatic Train Supervision and Train Protection with Manual Operation
        - Restricted Manual (RM) Mode: CBTC is disabled, with speed limits enabled
2. Provide a CBTC Towing Mode switch as follows:
    a. Type: See switch requirements in Table 5-4, Bypass Panel and in Section 21.

b. Location: Outside of reach of Operator, requiring Operator to leave seat to enable.

c. Function: Switch and circuits are powered only from the active cab (MC key switch ON). With an active cab, switch shall be functional in all cabs. With no active cab, the switch and circuits shall be de-energized and the switch nonfunctional.

d. Purpose: To inform various affected systems of Tow Mode activation, in order to adapt control logic, with positions of normal, pull, push. Mode switch shall notify CBTC which mode is enabled to broadcast vehicle length for moving block vehicle separation.

3. Provide a CBTC Bypass Switch as follows.

   a. Type: See switch requirements in Table 5-4, Bypass Panel, and in Section 21.

   b. Location: Outside of reach of Operator, requiring Operator to leave seat to enable.

   c. Function: Switch and circuits are powered only from the active cab (MC key switch ON). With an active cab, switch shall be functional in all cabs. With no active cab, the switch and circuits shall be de-energized and the switch nonfunctional.

4. CBTC Alerter Switch and CBTC RM Release Switch: See requirements in other parts of this Section and see Section 21.

5.11 Mock-up

Provide a mock-up of the Cab Console control panel for design review, using the controls specified in this Section. After design **approval**, turn the mock-up over to SEPTA for use as a training tool.

5.12 Contract Deliverables Requirements List (CDRL)

Master Controller Group Design Package
Cab Controls Design Package
Control Configuration and Interlocks Design Package
Cab Console Mock-up

5.13 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested
5. Software functional descriptions: Include top level control parameters and values

5-1 Master Controller Group Design Package

5-2 Cab Controls Design Package:

1. Manufacturer's literature and detail drawings for each type of switch and indicator, and for displays and devices not submitted under other sections.

2. List names of switches and indicators for which each submitted type will be used.

3. Drawings of the Cab Console and each other cab control panel showing the installed controls, indicators, and labels with components identified.

4. Submit cab displays under the sections in which they are specified, Section 13, Vehicle Communication Systems; and Section 17, Controls, Networks, and MDS.

5-3 Control Configuration and Interlocks Design Package

1. Schematics or diagrams detailing the timing logic of the Hotel Load timers, including orderly shutdown and startup of all connected devices.

5-4 Cab Console Mock-up:

1. Provide a mock-up of the control panel using the controls specified in this Section for design review.

2. After design **approval**, turn the mock-up over to SEPTA as a training tool.

5.14 Referenced Standards

The following standards are referenced in this Section:

IEC 60529	Degrees of Protection Provided by Enclosures
MIL-HDBK-759	Human Engineering Design Guidelines
SAE J287	Driver Hand Control Reach
SAE J1050	Describing and Measuring the Driver's Field of View
SAE J1139	Direction-of-Motion Stereotypes for Automotive Hand Controls
SAE J1517	Driver Selected Seat Position for Class B Vehicles - Seat Track Length and SgRP
SAE J1522	Truck Driver Stomach Position

Tilley AR. 2001. The Measure of Man and Woman: Human Factors in Design. Wiley.

END OF SECTION

Table of Contents

6.1 Scope

This Section includes:

1. Passenger doors and related equipment and controls
2. Bridge plates

6.2 General Description

Comply with the following:

1. Door type: Sliding-plug, flush with the vehicle body exterior skin when closed, or other **approved** configuration.
2. Protrusion from vehicle: Maximum 75 mm (3 in) during any portion of the open or close cycle.
3. Door size and configuration: As specified in Section 2, Design and Performance Criteria.

6.2.1 Cab Door

1. There must be a keyed door between the passenger compartment and the cab.

2. The cab door must have a one-way tinted window, allowing vision from the cab to the passenger compartment.

6.3 Door Design Requirements

6.3.1 Accessibility

Comply with the following for door controls, cutouts, access covers, and other specified functions:

1. Location: Accessible by the fifth-percentile female, as defined in The Measure of Man and Woman: Human Factors in Design.
2. Operating forces: Suitable for the fifth-percentile female, as defined in The Measure of Man and Woman: Human Factors in Design.

6.3.2 Door ADA and Interface Requirements

The doors and doorways shall meet ADA requirements, 49 CFR 38 Subpart D, and the station platform interface requirements of Section 2, Design and Performance Criteria.

6.3.3 Safety

Design the door system in accordance with the safety requirements of Section 2, Design and Performance Criteria. No single point failure in the door system or the vehicle controls shall cause:

1. A door to unlock or open when an Open request has not been commanded.

2. A Door Open or Enable command to be transmitted or responded to when the vehicle is in motion.
3. A Door Closed indication to be transmitted when any door is unlocked or open.
4. A traction interlock OK status when any door is unlocked or opened.
5. A Door Closed indication to be transmitted when an Enable or Open command is stored anywhere in the system.

6.3.4 Dynamic Performance

Comply with the following:

1. Doors shall be vibration and rattle free while the vehicle is stationary or in motion, and while doors are operating when the vehicle is stationary.
2. The door system, in conjunction with the vehicle's aerodynamics, shall prevent whistling and other objectionable noises at all vehicle speeds and wind speeds, as specified in Section 2, Design and Performance Criteria.

6.3.5 Adjustability

Comply with the following:

1. Door system: Include provisions for independent adjustments to location and alignment of the door operator, door panels, and other components to accommodate equipment installation, replacement, and system wear.
2. Mounting of sensors and switches: No readjustment shall be possible or necessary when a device is replaced.

6.4 Door Panels

6.4.1 Material and Construction

Comply with the following:

1. Material: Stainless steel, composite, or **approved** equivalent which complies with Section 16, Materials and Workmanship
2. Construction:

a. Panel shall be joined into an integral unit by adhesive bonding or resistance welding.

b. Edges and joints shall be completely sealed to prevent the entrance of moisture.

c. Reinforcement:

- Provide internal reinforcement for the attachment of door hardware. Reinforcement shall be mechanically attached to retain it when door hardware is being changed.
- Use HSLA reinforcement.

- Drain holes: Provide at the bottom of interior cavities if it is possible for condensation to form.
- Appearance: Interior and exterior skins of the door panel shall be free of dimples, warping, welding depressions, and other deformities as specified in Section 14, Interior and Exterior Appointments.

6.4.2 Windows

Each door panel shall contain a window that complies with the following:

1. Type: Laminated safety glass of the same materials and color as the side windows which complies with Section 14, Interior and Exterior Appointments.
2. Size:
    a. As high and wide as possible to allow passengers maximum view of station platforms and to make door positions more clearly identifiable to waiting passengers.
    b. Height shall be as high as possible to permit a passenger on the platform to see the door closing warning signal when the doors are closed.
3. Mounting: Windows shall be retained in the door panel by the same method used for passenger windows. The arrangement shall be watertight.

6.4.3 Strength Requirements

The door panel skin, structure, and mounting hardware shall sustain the following concentrated load with the door supported at the top and bottom in an agreed fixture:

1. Load: 890 N (200 lbf).
2. Load application: Perpendicular to the plane of the door at any location on the panel.
3. Load-bearing surface: 100 mm by 100 mm (4 in by 4 in).
4. Deflection under these conditions: Maximum 10 mm (0.4 in), with no permanent deformation after the force is removed.

6.4.4 Sealing Requirements

Comply with the following for door panel and doorway seals:

1. Sealing material: Elastomer complying with Section 16, Materials and Workmanship.
2. Weather seal: Watertight under these conditions:
    a. When the vehicle is being washed.
    b. For all service speeds with the worst-case combination of climatic conditions described in Section 2, Design and Performance Criteria.
3. Air seal: Sufficient to maintain required HVAC pressurization.

4. Seal locations:

    a. Vehicle body edges.

    b. Forward edge of the door where the panels meet in the closed position.

    c. Seal shall have a contour designed to mate with the seal on the other panel.

    d. Seal shall be integrated into the functionality of the obstruction detection system.

    e. Top edge of the door.

    f. Bottom edge of the door.

5. Maintainability: Apply seals in a manner that enables them to be easily replaced with the door panels in place.

6.5 Manufacturing and Installation Requirements

Comply with the following for doors and door equipment:

Manufacturing:

Use jigs and fixtures for doorways, mounting points, hardware, and other door-related features of the vehicle, with dimensions and tolerances as defined by the door manufacturer, and in accordance with the standards of workmanship specified in Section 16, Materials and Workmanship.

Doors and door equipment shall be interchangeable from one location to any other location and from vehicle to vehicle without modification.

Installation:

1. Install according to the door manufacturer's requirements and tolerances. Modification of door equipment is prohibited.

2. Make permanent to each doorway shimming or other adjustments made to achieve proper door fit.

6.6 Performance Requirements

Comply with the following:

1. Door motion: Smooth acceleration and motion, free of shock and impact. At the end of travel, door shall have smooth deceleration in both the opening and closing directions.

2. Control delay-time: Maximum 0.15 second from receipt of a trainline door command signal from the Cab Console or local door pushbutton to the first motion of a door panel.

3. Door panel operating speed:

    a. Initial setting: 200 mm/s (8 in/s) in opening and 200 mm/s in closing, +/- 30 mm/s (1.2 in/s), from time of first motion to the point of completion, including cushioning.

b. Maximum door closing speed: 300 mm/s (12 in/s).

c. Operating speeds shall be adjustable by the Owner via Portable Test Unit (PTU) (see Section 19, System Support).

6.7 Door Operator

6.7.1 General

For door movement, provide one electrically powered door operator per door leaf that complies with the following:

1. Power: Sufficient to open and close doors at specified performance levels with the most unfavorable ambient wind, vehicle pressurization conditions, and grade.
2. Operation: Left and right door panels shall move simultaneously.
3. Design: Unitized and interchangeable among door leaves in other doorway locations.

6.7.2 Door Operator Mechanical Requirements

Comply with the following:

1. Connection between door operator and door panels:
2. Mechanical via screw shaft, linkages, or as **approved**.
3. Fluid or pneumatic devices are prohibited.
4. Location of door operator equipment:
5. In the transom area above the doorway.
6. Concealed, except as necessary for the sliding mechanism, such that it is not directly visible when the door is opening and closing, or when door is in fully closed position.

Access to door operator:

1. By opening a cover or removing an access panel, without the need to move or disconnect other equipment. For keying requirements, see Section 14, Interior and Exterior Appointments.
2. Provide sufficient clearance and access space to maintain components on the door operator assemblies, and to remove the assemblies as complete units.

Door tracks: Locate within the vehicle body or within the door panel.

1. Separate sliding door lock assemblies: Locate within the vehicle body, if required by the door design.

6.7.3 Door Operator Electrical Requirements

Comply with the following:

Power source: DC low-voltage power supply (LVPS).

Voltage range: Capable of operating over the entire voltage range of the LVPS and emergency power without affecting the reliability, specified performance, or service life of the door operator.

Stall current:

1. The door operator shall be capable of withstanding stall current indefinitely.
2. Alternately, it shall be capable of detecting stall current and removing power if it persists for a preset time, and shall reset automatically when the door controls are cycled to open the doors.
3. Stall current shall have no adverse effect on the reliability and service life of the equipment.

6.8 Door Control System

6.8.1 General

Comply with the following:

1. Door operator control type: Microprocessor-based control logic unit.
2. Location: Either immediately adjacent to or within the door operator compartment.

Design requirements:

1. Configure door control signals in a completely left/right side of vehicle configuration.
2. Comply with Section 2, Design and Performance Criteria, and Section 17, Controls, Networks, and MDS, and include provisions to interface and interact with APC and NVR.

6.8.2 Control and Monitoring

The door control system shall control and monitor the door system, including the following:

Door motion control:

Opening speed.

Closing speed.

Closing forces.

Detection of stalls.

Acceleration and deceleration.

Door-close time delays.

Command and status monitoring:

Door trainline commands from the Cab Console and local passenger switches.

No-motion status.

Door obstructions.

Vehicle level status; see Load Leveling section in Section 11, Truck Assemblies.

Door Position Monitoring:

Monitor continuously from fully opened to fully closed.

For position sensing, provide non-contact proximity-type sensors not requiring adjustment.

This position sensing is in addition to the position sensing requirements in the Door Status (Open) Interlock Requirements section, below.

6.8.3 Diagnostics, Data Network, and Adjustments

6.8.3.1 Diagnostics

Comply with the following:

Status of door system: Available via a diagnostic system integral to the door control system software and visible on the Train Operator Display (TOD).

Monitored items to be logged by the MDS if outside of acceptable parameters:

Critical internal functions.

External inputs.

Mechanical door system, including door open, closed, and lock status.

Actual door performance, such as door speeds on opening and closing.

Access to diagnostics: Available from each door control logic unit via separate connector at the control logic unit and via the network connector itself.

6.8.3.2 Data Network

Each door control logic unit shall be linked to the vehicle's data network:

Status and diagnostic information: Shall be available at a single common location, and on the TOD, from each door. See Section 17, Controls, Networks, and MDS.

Inter-communication: Door control logic units in the vehicle may communicate with each other, but interfaces with the vehicle door and commands and no-motion interlocks shall be on a per-doorway basis.

Failure of network links:

Shall have no effect on door operation.

Shall be announced at the diagnostics port and TOD.

6.8.3.3 Adjustments

Comply with the following for adjustments of the door control system:

Permissible adjustments: All operating variables, including but not limited to the following:

Door opening and closing speeds

Door closing forces

Door timing

Adjustment access: Adjustments to individual doors shall be locally using a PTU. Adjustments to all doors shall be through software update released via the vehicle network.

6.9 Door Operation

6.9.1 General

Doors may be opened using switches on the Cab Console or the crew door key-switch.

6.9.2 Door Operation Restrictions

Door operation shall be possible only under the following conditions:

The vehicle has achieved no-motion; and

The vehicle has achieved correct floor height (see Section 11, Truck Assemblies); and

The Master Controller (MC) is in the Full Service Brake (FSB) position; and

If the MC key switch is in the Off position, the Hotel Load timer has not yet expired.

6.9.3 Cab Console Controls

Provide pushbutton door controls on the Cab Console as specified in Section 5, Operator's Cab Controls. In addition, comply with the following:

Door Open:

The Open command shall be interlocked with the no-motion circuitry both in the cab, and at each doorway, independently of the Door Enable command;

An Open command shall override any ongoing obstruction detection activities, and reset the obstruction detection counter to zero.

Door Enable:

The Door Enable command shall be interlocked with the no-motion circuitry both in the cab and at each doorway.

The door enable function shall not be affected by vehicle or local network failures.

Door Close: Upon successful closing, the door obstruction counter shall be reset to zero.

Trainlines: Momentary energization of the Door Enable, or Door Open trainline by the Cab Console pushbuttons shall cause the trainlines for the respective side of the train to latch in the energized state until unlatched and de-energized by the Cab Console Door Close pushbutton.

6.9.4 Passenger Controls

6.9.4.1 Pushbuttons and Tape Switches

Provide pushbuttons or tape switches in the following areas:

At each doorway:

Provide illuminated pushbutton inside the vehicle to activate the passenger stop request:

Type: Momentary contact, heavy-duty, recessed to prevent inadvertent operation, suitable for frequent use in the SEPTA environment, rated IP66 per IEC 60529.

Illumination: Green and red LED, to indicate enabled and non-enabled status, respectively.

Color: Pushbutton and surrounding bezel color-coded with an **approved** color – Red for PEI.

Identification: Switch nomenclature or symbol molded into the switch in raised lettering, dimensioned to permit sensing by a visually impaired person.

At each mobility aid parking area:

Provide a means for passengers in mobility aids to activate the passenger stop request, such as with a linear or tape switch, mounted horizontally, or other **approved** device:

Type: Momentary contact, heavy-duty, impact resistant, easy to operate, water resistant, suitable for frequent use.

Color: Provide colored switch, or mount over a colored band at least 25 mm (1 in) wide to improve visibility, using an **approved** color – Yellow for tape switches.

Identification: Nomenclature or symbols indicating function of switch and how to operate, as suitable for the type of switch, dimensioned to permit sensing by a visually impaired person, on or adjacent to switch.

In the seating areas between the doorways and the seating areas adjacent to the cab:

Provide a means for passengers to activate the passenger stop request, such as with a linear or tape switch, or other **approved** device.

Location: Provide five on each side, for a total of ten.

Type: Momentary contact, heavy-duty, impact resistant, easy to operate, water resistant, suitable for frequent use.

Color: Provide colored switch, or mount over a colored band at least 25 mm (1 in) wide to improve visibility, using an **approved** color – Yellow for tape switches.

Identification: Nomenclature or symbols indicating function of switch and how to operate, as suitable for the type of switch, dimensioned to permit sensing by a visually impaired person, on or adjacent to switch.

6.9.4.2 Passenger Stop Request Function

Door Enable command not activated by the Operator:

Pressing the passenger seating area and mobility aid parking area linear or tape switch shall activate the passenger stop request function.

Activation of the passenger stop request shall initiate the following:

Passenger seating area and mobility impaired parking area:

Visual indication

Sound the local passenger stop request chime

Operator’s cab:

Sound an audible alert for 0.5 seconds, then latch Off.

Illuminate a light on the Cab Console.

Reset audible alert and light after the doors have been closed by the Operator via the Door Close cab control.

6.9.5 Door Open Function

Door Open command activated by the Operator:

Door shall remain open until commanded closed with the Door Close pushbutton.

6.9.6 Crew Door Key-Switch

Provide crew door key-switches on each vehicle:

Location:

Only at the doorways closest to the cab, on each side of the vehicle.

Shall be segregated to the left and right of the operator and highlighted.

Inside and outside the vehicle, a total of two per doorway and eight per vehicle.

Locate outside switches beyond the open position of the door panel.

Switch Description:

Weatherproof, momentary electrical rotary switch.

Three positions: Open, Neutral, and Close with spring return to center (Neutral).

Operated by a key (see Section 14, Interior and Exterior Appointments, for the Key Assignment Table).

Switch Operation:

Turning the switch momentarily to the Open position, without holding it in that position, shall cause the adjacent door to open fully. If both cabs are keyed Off it shall turn On the Auxiliary On/Off switch and start the Hotel Load timer (See Section 5, Operator's Cab Controls).

Turning the switch momentarily to the Closed position, without holding it in that position, shall cause the door to completely close and lock.

Comply with the following:

Crew door key-switch and related circuits shall have applied power only when the vehicle has reached no motion and the MC is in a brake position.

Arrange crew door key-switch and adjacent door operator such that they can function independently of the Cab Console controls.

Crew door key-switches and associated circuits shall be considered a safety circuit, and shall meet the safety requirements of Section 2, Design and Performance Criteria.

6.9.7 Loss of Control Power

In the event of loss of local control power, doors shall remain in the last commanded position during absence of control power and when power is restored.

6.10 Door Locks

Door panels shall be positively retained in the closed position via mechanical means:

Lock function: Separate mechanical lock, or an over-center function of the operating linkage, if the linkage is directly connected to the door panels.

Drive belt (if used): Lock mechanism shall not rely on the belt.

Lock engagement: Automatic when both door panels reach the closed position; electrical power shall not be required to maintain locked status.

6.11 Door Obstruction Detection

6.11.1 General

The door system shall automatically detect obstructions, prevent a person from becoming entrapped, and limit the forces imparted to a person standing anywhere in the doorway.

6.11.2 Detection Methods

Provide integrated design using:

Electrical sensitive edge: Incorporate within the leading edge of each door panel. The design, sensitivity, and response of each panel to obstructions shall be the same.

Restrictions in door motion: Detect via current sensing, speed vs. time tracking, or other **approved** method.

6.11.3 Operation Requirements

Upon detection of an obstruction, the door panels in the affected doorway shall perform as follows:

Immediately decelerate.

Open and remain open for a preset period controlled by an adjustable time delay circuit, adjustable in software from 0 to 10 seconds.

Attempt to close.

If the obstruction is no longer detected, close and lock.

If the obstruction is still detected, continue to recycle for an adjustable preset number of times (including at least 0 to 10 recycles).

If the recycle count is exceeded, remain in the open position until reset by the Operator via cab controls. See Section 5, Operator's Cab Controls, for a functional description of door controls.

The recycle count, initially set at five, shall be software settable by the use of a PTU or **approved** equivalent method.

6.11.4 Sensitivity Requirements

Comply with the following:

Each door panel's obstruction detection system shall detect an obstruction in the path of a closing door.

The force exerted on an obstacle required to trigger the detection of an obstruction shall not exceed the following values when the door is powered to close. APTA PR-M-S-018-10, Appendix A defines these values and a test procedure that shall be used to measure them in the required test.

Peak force (F_p): 300 N (68 lbf).

Effective force (F_e): 200 N (45 lbf).

The obstruction detection system shall detect the following for each panel separately:

Flat bar:

Size: 6.5 mm (0.25 in) wide and 75 mm (3 in) high and sufficient length to span the door seals

Position: Held rigidly between and perpendicular to the door panel, as a hand might be held to stop the doors

Sensitive Area: Everywhere along the length of the panel except the uppermost 75 mm (3 in) measured from the top of door opening and in the lowermost 25 mm (1 in) of the door leading edge measured from the top of the door opening threshold

Cylindrical object:

Size: 10 mm (0.375 in) in diameter and sufficient length to span the door seals

Position: Held rigidly between and perpendicular to the door panels

Sensitive Area: All locations along the length of the door leading edges, except in the uppermost 75 mm (3 in) measured from the top of door opening and lowermost 25 mm (1 in) of the door leading edge measured from the top of the door opening threshold

6.11.5 Obstructions Not Detected

The door edge shall allow a thin flexible object not detected by the obstruction detection system, such as an article of clothing, to be pulled free from the leading edge of a door that is fully closed and locked.

6.12 Manual Door Release Mechanism

6.12.1 Functional Description

Provide interior and exterior manually operated door release mechanisms to permit both door panels to be fully opened locally regardless of the availability of electrical power or door status, including a previously cutout door:

1. Activation of the release device shall interrupt the door status interlock, causing propulsion power to be removed and a FSB application to be applied.
2. Power shall be removed from the door motor, but the door controller shall remain active if power is available.
3. The door controller shall monitor and annunciate activation of the manual release to the vehicle network.
4. The release device shall not electrically bypass the local no-motion interlock.
5. Activation of the release device shall unlock the door and open the door approximately 25 mm (1 in) to permit free and uninhibited movement of the door leaf.

6.12.2 Interior Manual (Emergency) Door Release

APTA-PR-M-S-018-10 Section 2.8: 1 interior emergency release and 1 exterior emergency release per exterior side door. APTA-RT-VIM-S-023-12 Section 2.1: For vehicle length between 60 ft and 90 ft, 4 emergency access points per side of the car.

Provide a lever or pull knob device on the interior of each doorway meeting the following requirements:

1. Force necessary to actuate the Interior/exterior emergency release mechanism shall not exceed 30 lbf using a lever-type mechanism or 50 lbf using a “T” handle–type mechanism.
2. Design and location: In an **approved** location accessible to all passengers, selected to prevent inadvertent operation and discourage everyday use.

3. Signage: Explain operation in an emergency, warn against unlawful use, and advise that emergency door opening device is also an emergency stop device. Signage is subject to **approval** and shall be in accordance with Section 14, Interior and Exterior Appointments.

4. Annunciation when activated: As specified in the Indicators and Annunciators section, below.

6.12.3 Exterior Manual Door Release

APTA-PR-M-S-018-10 Section 2.8: 1 interior emergency release and 1 exterior emergency release per exterior side door. APTA-RT-VIM-S-023-12 Section 2.1: For vehicle length between 60 ft and 90 ft, 4 emergency access points per side of the car.

Provide a lever or pull knob device on the exterior of each doorway meeting the following requirements:

1. Force necessary to actuate the Interior/exterior emergency release mechanism shall not exceed 30 lbf using a lever-type mechanism or 50 lbf using a “T” handle–type mechanism.

2. Design and location: Above platform level, large enough to fit a gloved hand.

3. Cover: Flush with the side of the vehicle when closed, waterproof. Cover shall have a frangible opening and be equipped with a lock for use by maintenance personnel.

4. Signage: Provide adjacent to each cover, suitable for emergency responders or other users and in accordance with Section 14, Interior and Exterior Appointments.

5. Annunciation when activated: Same as the interior device, except Passenger Emergency message shall not be sent when activated.

6.12.4 Reset Device

Comply with the following:

1. Function: Restores doors to normal operating condition after use of the manual release mechanism.

2. Operation: Via barrel key (see Section 14, Interior and Exterior Appointments, for the Key Assignment Table).

3. Location: Within the door control panel or transom area above the doors.

6.13 Door Interlock Requirements

6.13.1 No Motion Interlock

Electrically interlock door operators and controls in a failsafe manner with the vehicle's no-motion circuits, such that doors can be powered, opened, or released only when the vehicle has reached no-motion:

1. No-motion lost: Door motor Open wiring shall be switched Open with critical circuit relays. Door motor's Close circuits shall remain connected.

2. Motion detected: Close command shall be issued to all doors in the vehicle.

3. Vehicle in motion: Diagnostic and fault monitoring and logging shall remain active.

6.13.1.1 Controllers

1. Shall monitor no-motion circuits independent of the motor interlocks.
2. Shall ignore Open or Enable trainline commands without a no-motion signal present and if this condition occurs, issue a fault indication.

6.13.2 Door Status (Open) Interlock

Provide circuitry to monitor door panel position and door lock status for each side of the vehicle:

1. Components: High reliability position-sensing switches for each panel, and separate switches for detection of lock status.
2. Switches shall positively and directly detect actual panel and lock positions. These switches are in addition to those specified above for the Door Control System.
3. Switch mounting shall be such that no readjustment is necessary when a switch is replaced.
4. Tolerances for switch, switch mounting device, and door component shall not permit a newly installed switch to indicate a false close or locked status.

6.13.2.1 Circuitry

1. Configure status signals in a completely separate left/right side of vehicle configuration.
2. Wire switches on each side of the vehicle in series.

6.13.2.2 Function

1. Door panels properly closed and locked: Activate a Summary Door Status non-welding critical circuit relay.
2. One or more closed or locked switches not made up:
3. De-energize the Summary Door Status relay
4. Illuminate the Cab Console Door-Open light for that side of the vehicle
5. Remove propulsion power
6. Apply FSB

6.13.2.3 Operating sequence if the Operator attempts to apply power with a door panel not closed and locked

1. Summary Door Status relays must be energized
2. MC must be moved to the FSB position
3. Brakes can be released, and power applied

4. No false signals

5. No single point failure in the loop circuit shall cause a false door closed and locked signal.

6. Where failures in the loop circuit are not self-annunciating, they shall not lead to a false Doors Closed and Locked signal, from the door interlock circuit, or in association with other single-point failures.

6.14 Door Bypass Devices

6.14.1 General

Provide bypass devices to circumvent specific door system faults so that the vehicle can continue in revenue service, or be removed from revenue service and returned to the maintenance facility, or moved to clear the line.

6.14.2 Door Interlock Bypass

Provide a door interlock bypass feature in each cab (see Section 5, Operator's Cab Controls):

1. It shall permit movement of the vehicle under emergency conditions if not all doors are sensed as being closed and locked, and the source of the fault cannot be readily determined.

2. It shall bypass the door status interlock so that the brakes can be released, and power applied.

3. It shall not give a false Doors Closed indication.

6.14.3 Door Cutout

Provide a key-activated door cutout device in an **approved** location adjacent to each door:

1. Door cutout device shall perform the following functions:

2. Disconnect door motor from any source of electrical power.

3. Bypass door-closed and door-locked interlocks for that door.

4. Ensure that the door remains closed by mechanical restraint, but allows override by the manual door release devices, which allow the door to be opened in case of emergency.

5. Illuminate the local passenger pushbutton light Red.

6. Activate the door cut-out trainline.

7. The door controller shall remain active when the door is cut out.

6.15 Indicators and Annunciators

6.15.1 Doors to Open/Door Locked Out

Provide audible and visual notification to indicate the following:

1. Doors that are to open: The notification should be made on the interior and only once or twice, but not constant.
2. Door out of service: Provide a second and different alarm when a door is out of service and not going to open.
3. Interior: The annunciation shall be door specific.
4. Exterior: Provide indication that the door on the platform side is not available for normal use.
5. Indicators shall be discrete from other door system indicators so that passengers and crew are not confused.

6.15.2 Door Open Indications

Submit Door Open indications and layouts for the TOD for **approval**.

Provide a Door Open indicator status light at each doorway in an **approved** location to allow the Operator to identify the location of the open door.

6.15.3 Manual (Emergency) Door Release

Activation of an interior manual door release (Passenger Emergency) shall cause the following:

1. At the doorway: Audible and visual warning.
2. In each cab (door controller active):
3. Audible alert
4. On TOD: Annunciation of "DOOR EMERGENCY" at specified door.

6.15.4 Door Closing Warning Announcements

Provide 49 CFR 38 Subpart D compliant audible and visual door closing warnings independently for each doorway:

Audible door closing warning:

1. Duration: For 2 seconds prior to doors closing (adjustable 0 - 2 seconds)
2. Sound: Pleasant two-tone alarm, audible inside and outside the vehicle
3. Source: The warning may be generated by any of the systems, with **approval**, such as the following:

a. The local door control system

b. The PA system

c. The automatic passenger information system (APIS)

d. Visual door closing warning:

Timing: Shall activate at the same time as audible warning

Appearance: Flashing amber

Location: Both sides of each doorway on the side of the door frame

Visibility: Inside and outside the vehicle with doors in the open position

6.16 Door Control Signals

See Section 17, Controls, Networks, and MDS, for door system control signal requirements.

6.17 Retractable Bridge Plates

6.17.1 Design

6.17.1.1 Integration

Integrate the retractable bridge plate system with the door system.

6.17.1.2 ADA and Interface Requirements

Comply with the following:

Bridge plates shall meet ADA requirements, 49 CFR 38 Subpart D, and the station platform interface requirements of Section 2, Design and Performance Criteria.

The retractable bridge plate design shall comply with 49 CFR Part 38.83 (c), Vehicle ramp or bridge plate, except that the bridge plate width shall be no less than the width of the fully open doorway specified in Section 2, Design and Performance Criteria.

6.17.1.3 Safety

Design retractable bridge plates in accordance with the safety requirements of Section 2. No single point failure of the bridge plate system shall cause:

A bridge plate to unlock or deploy when a deploy request has not been commanded.

A bridge plate deploy command to be transmitted or responded to when the vehicle is in motion.

A bridge plate retracted and locked indication to be transmitted when any bridge plate is unlocked or deployed.

A traction interlock okay status when a bridge plate is unlocked or deployed.

A bridge plate retracted indication to be transmitted when an unlock or opening command is stored anywhere in the system.

6.17.1.4 Dynamic Performance

Comply with the following:

Bridge plates shall be vibration and rattle free while the vehicle is underway and when the vehicle is stationary and bridge plates are deployed.

The bridge plate system, in conjunction with the vehicle's aerodynamics, shall prevent whistling and other objectionable noises at all vehicle speeds and wind speeds, as specified in Section 2, Design and Performance Criteria.

6.17.1.5 Adjustability

Include provisions in the bridge plates for independent adjustments to location and alignment of the bridge plate operator and other components to accommodate equipment installation, replacement, and system wear.

6.17.2 Manufacturing and Installation

Comply with the following:

Manufacturing:

Use jigs and fixtures for bridge plate, components, and mounting holes for hardware, in accordance with the standards of workmanship specified in Section 16, Materials and Workmanship.

Bridge plates and related equipment shall be unitized, easily removable, and interchangeable from one location to any other location and from vehicle to vehicle without modification.

Installation: According to the manufacturer's requirements and tolerances.

6.17.3 Location, Size, and Strength

Comply with the following:

Location: The bridge plate and its mechanisms shall be beneath the door threshold at locations specified in Section 2, Design and Performance Criteria.

Size: The bridge plate shall span the full useable width of the door opening and be capable of filling the vertical and horizontal gaps encountered at station platforms.

Strength: The bridge plate shall support a load per 49 CFR 38.83 (c) (1), Design load.

6.17.4 Retractable Bridge Plate Configuration

Comply with the following:

Doorway threshold:

Include an interior hinged portion that extends with the bridge plate, such that the bridge plate and doorway threshold form a continuous ramped surface.

The threshold specified in Section 14, Interior and Exterior Appointments, may be integral to the bridge plate assembly at bridge plate doors.

Bridge plate slope: Shall not exceed requirements of 49 CFR 38.83 (c) (5), Slope

Bridge plate and threshold edges:

Thickness: Minimum 3 mm (1/8 in) and maximum 13 mm (1/2 in)

Treatment: Beveled, and rounded to eliminate sharp edges

Wear strip:

Type: Replaceable

Material: Same as bridge plate

Location: At or beneath the outboard edge of the bridge plate where it contacts the wayside platform

Heaters: The bridge plates shall be equipped with heaters to ensure bridge plates remain operable during climatic operating conditions specified in Section 2, Design and Performance Criteria.

Platform interface: The bridge plate shall function correctly, and without interference, with the station platform interface requirements of Section 2, Design and Performance Criteria.

6.17.5 Material and Components

All materials and fasteners to be corrosion resistant, including the following:

Structural components: Aluminum or stainless steel.

Guide rollers (if used): Stainless steel with permanently lubricated bearings.

Other rolling and sliding surfaces: Designed not to require periodic lubrication.

Bridge plate and threshold: Cast aluminum or stainless steel.

Bridge plate surface: Slip resistant, with static coefficient of friction 0.8. Adhesive-backed, non-skid "tape" or sheets are prohibited.

6.17.6 Bridge Plate Operator

Comply with the following:

Type: Electrically operated.

Operation:

Deploy bridge plate horizontally outward and then allow it to tilt downward to meet and rest on platform surface.

The bridge plate shall be able to extend and then retract without landing on a platform.

Vertical range of motion: Sufficient to allow bridge plate to rest on the platform surface by gravity alone under all specified conditions.

Manual operation: Provide a manual bridge plate operator that allows bridge plate to be manually deployed or retracted in the event of power failure:

The mechanism shall not be readily accessible to passengers or require removal of any floor paneling.

Bridge plate interlocks shall not be defeated by manual operation.

6.17.7 Control System

6.17.7.1 General

The bridge plate controller may be integrated with the door controller.

6.17.7.2 Control and Adjustment

The bridge plate control system shall control and allow adjustment of the following, and similar features via PTU and software provided by the bridge plate supplier:

Extend speeds, forces, and timing.

Extend obstruction detection threshold force.

Retract speeds, forces and timing.

Retract obstruction detection threshold force.

6.17.7.3 Monitoring and Position Sensing

Comply with the following:

The bridge plate controller shall monitor the performance and position of the bridge plate to accomplish the following:

Detect stalls or obstructions over the full travel length.

Detect positioning on extension and retraction.

Detect lock status.

Position and lock status shall be via non-contact proximity-type sensors not requiring adjustment.

6.17.8 Operation

6.17.8.1 General

Bridge plates shall be extended by the Operator only. See Section 5, Operator's Cab Controls, for Operator control.

6.17.8.2 Operation Restrictions

Bridge plate operation shall be possible only under the following conditions:

The vehicle has achieved no-motion, and

The Master Controller is in the FSB position, and

The vehicle is at the correct height, and

The associated door is in the closed position, and

The MC key switch is in one of the following positions:

On position.

The Operator has Enabled the doors, then moved the MC key switch to the Off position. This shall enable the local bridge plate request pushbuttons until the Hotel Load timer has expired.

6.17.9 Passenger Controls

6.17.9.1 Control Switches

At each bridge plate doorway:

1. Provide illuminated bridge plate request pushbuttons, one inside the vehicle and one outside the vehicle:

Type and illumination: Comply with the Pushbuttons and Tape Switch section, above.

Color: Comply with the Pushbuttons and Tape Switch section, above, except color shall be different from door control switches.

Identification: Comply with the Pushbuttons and Tape Switch section, above, except also provide the International Symbol of Accessibility (wheelchair) on or adjacent to the switch.

At each mobility aid parking area: Provide a means for passengers in mobility aids to activate the passenger bridge plate request, such as with a linear or tape switch, mounted horizontally:

Type: Comply with the Pushbuttons and Tape Switch section, above.

Color: Comply with the Pushbuttons and Tape Switch section, above, except color shall be different from stop request switches.

Identification: Comply with the Pushbuttons and Tape Switch section, above, except also provide the International Symbol of Accessibility (wheelchair) on or adjacent to the switch.

6.17.9.2 Passenger Control Functional Description

The local passenger bridge plate request pushbuttons shall operate as follows:

When a pushbutton is depressed:

In the passenger area, sound the local passenger stop request chime.

In the Operator’s cab, sound an audible alert for 0.5 seconds and illuminate Bridge Plate Request indicator. Once activated, the audible alert shall be latched off and indicator shall stay illuminated until the doors have been closed or the bridge plate retracted by the Operator.

Send a bridge plate request to all bridge plate controllers on the vehicle. The Operator door and bridge plate commands shall control which bridge plate is extended.

6.17.10 Loss of Control Power

In the event of a loss of local control power, the bridge plate shall remain in the last commanded position during absence of control power and when power is restored.

6.17.11 Locks

The bridge plate shall be positively retained in the retracted position via mechanical means:

Type: May be a separate mechanical lock or an over-center function of the operating linkage, if the linkage is directly connected to the bridge plate.

Drive belt (if used): Lock mechanism shall not rely on the belt.

Operation: Lock shall automatically engage when bridge plate reaches retracted position and shall not require electrical power to remain locked.

6.17.12 Performance

Comply with the following:

Bridge plate motion: Smooth and free of shock and impact.

Control delay-time: Maximum 0.15 seconds from receipt of a bridge plate command signal by the Operator or local bridge plate pushbutton to the first motion of the bridge plate.

Bridge plate operating speed:

Initial setting: 200 mm/s (8 in/s) in extending and 200 mm/s (8 in/s) in retraction plus or minus 30 mm/s (1.2 in/s), from time of first motion to the point of completion, including cushioning.

Maximum speed: 300 mm/s (12 in/s).

Operating speeds shall be adjustable by SEPTA via PTU (see Section 19, System Support).

6.17.13 Obstruction Detection

6.17.13.1 General

The bridge plate system shall automatically detect obstructions, prevent a person from becoming entrapped, and limit the forces imparted to a person when the bridge plate is extending or retracting.

6.17.13.2 Detection Methods

The bridge plate control equipment shall detect restrictions in bridge plate motion via current sensing, speed vs. time tracking, or other **approved** method.

If the bridge plate is equipped with movable side barriers, the detection shall detect an obstruction within the movement of the side barriers.

6.17.13.3 Operation Requirements

Comply with the following:

Upon reaching the detection threshold, the bridge plate shall perform as follows:

Immediately decelerate and stop.

Send a fault message to the Operator.

Fault reset: After activation of Operator bridge plate Retract/Extend command the bridge plate shall continue with the last commanded movement, extend or retract.

6.17.13.4 Sensitivity Requirements

Comply with the following:

Detection threshold: Force opposing bridge plate motion exceeding 130 N (29 lbf).

Threshold adjustment: User adjustable from 130 N (29 lbf) to 400 N (90 lbf).

6.17.14 Indicators and Annunciators

6.17.14.1 Bridge Plate Extended Indicators

Provide bridge-plate-extended indicator status lights:

Quantity: Two, one for each side of the vehicle.

Location: On the TOD.

Activation: When any bridge plate on the associated side of the vehicle is sensed as being unlocked, extended, or both.

6.17.14.2 Bridge Plate Warning Announcement

Provide audible and visual door closing warnings independently for each bridge plate indicating that bridge plate is moving, extending, or retracting:

Audible bridge plate warning:

Activation: 2 seconds prior to the bridge plate moving (adjustable 0 - 2 seconds)

Termination: When extension or retraction is complete

Sound: Different from the audible door warning, generated electronically by the local bridge plate control system, audible inside and outside the vehicle

Location: Vehicle exterior, adjacent to the bridge plate

The warning shall function only at bridge plates where motion is commanded

Visual bridge plate warning:

Timing: Provide at the same time as audible warning

Appearance: Flashing amber

Location: Both sides of each doorway on the side of the door frame

Visibility: If the visual door warning cannot be seen from outside the vehicle with the doors closed, provide a duplicate weatherproof device on the outside of each doorway

The door closing visual warning can be used for the bridge plate movement visual warning

6.17.14.3 Status Indicators

Show the following bridge plate status indications on the TOD:

Extended

Enabled

Retracted and Locked

Cutout

Failure or fault

6.17.15 Bridge Plate Interlock Requirements

The following door interlocks shall also apply to bridge plates:

No Motion Interlock: Requirements for door operators and controls shall apply to bridge plate operators and controls, such that the bridge plates can be powered and released only when the vehicle has reached no motion.

Door Status (Open) Interlock: Requirements for components and circuitry to monitor door panel position and lock status shall apply to bridge plates, and shall indicate whether door panels are properly closed and locked and bridge plates are retracted and locked.

6.17.16 Bridge Plate Bypass Devices

6.17.16.1 General

See the Door Bypass Devices section, above, for details related to these devices. Requirements for doors apply also to bridge plates.

6.17.16.2 Door Interlock Bypass Applied to Bridge Plate

The door interlock bypass switch shall bypass the interlock which prevents propulsion in case of a deployed bridge plate, in addition to its function related to the door interlock circuit, as specified in Section 5, Operator's Cab Controls, and this Section.

6.17.16.3 Bridge Plate Cutout

Provide a bridge plate cutout device in an **approved** location adjacent to each bridge plate door, behind a locked panel, that performs the following functions:

Disconnects bridge plate motor from any source of electrical power.

Ensures that the bridge plate remains retracted by mechanical restraint.

Indicates bridge plate cutout on TOD.

Illuminates the local bridge plate pushbutton light Red.

6.18 Contract Deliverables Requirements List (CDRL)

Door System Design Package
Door-Platform Interface Design Report
Door Control System Design Package
Door Diagnostics and Adjustments Design Package
Door Control Switches Design Package
Obstruction Detection Design Package
Door Interlock Design Package
Door Indication and Warning Design Package
Bridge Plate Design Package

6.19 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

Detail drawings: Top level assemblies, installation, and other drawings if requested

Functional description

Control schematics

Component ratings: Top level components, and ratings of other components if requested

Software functional descriptions: Include top level control parameters and values

6-1 Door System Design Package:

1. Dimensioned drawings of door with general description and materials
2. Door operator details and drawings
3. Door lock and details
4. Manual (emergency) release details and drawings
    a. Include interior and exterior manual release and cover for exterior manual release
    b. Include graphics

6-2 Door-Platform Interface Design Report:

1. Vehicle dynamic envelope drawing.
2. Detail drawings: Show platform interface dimensions, including platform and vehicle tolerances.

6-3 Door Control System Design Package:

1. Door controller.
2. System circuit diagrams.
3. Sneak circuit and single point failure analysis, as specified in Section 2, Design and Performance Criteria.
4. Interlocks and safety critical functions

6-4 Door Diagnostics and Adjustments Design Package:

1. System circuit diagrams
2. List of available adjustments

6-5 Door Control Switches Design Package:

1. Data sheets for crew door key-switches and passenger control-switches, including sizes, bezels, colors, graphics, and other features
2. Sample of each switch, pushbutton, and tape switch. Switches will be returned to the Contractor.

3. Location drawings for all switches, including both plan and elevation views

4. Submit door control switches located in cab under Section 5, Operator's Cab Controls, not as part of this package

6-6 Obstruction Detection Design Package:

1. Design and methods for door obstruction detection

2. Test procedure used to verify the obstruction detection performance requirements in accordance with APTA PR-M-S-18-10

3. Demonstration of the sensitivity of the obstruction detection system to detect

4. Door closing kinetic energy calculation and results.

6-7 Door Interlock Design Package:

1. No motion interlock:

   a. System circuit diagrams
   b. Critical circuit relays

2. Door Status (Open) Interlock:

   a. System circuit diagrams
   b. Position sensing switches
   c. Non-welding critical circuit relay

6-8 Door Indication and Warning Design Package:

1. List of warnings and indications with location and features of each

2. Door Closing Audible Warning: Tone and intensity

3. Door Closing Visual Warning:

   a. Location drawing
   b. Product information
   c. Sample demonstration

6-9 Bridge Plate Design Package:

1. Functional description with sufficient detail to confirm compliance with the Specifications.

2. Parts list.

3. Drawings of bridge plate in the retracted and extended positions, including sections and assembly drawings.

   a. Show the platform interface in the extended position and indicate bridge plate slope, using specified platform height.
   b. Show details of adjustability

c. Show details of locking in the retracted position
d. Show details of manual deployment mechanisms.
e. Show all dimensions, including thickness of materials.
f. Show details of non-skid surface.
g. Indicate materials on the drawings.

4. Circuit diagrams and schematics if not incorporated into door submittals.

5. Details of locks, manual release, and securement of a cut-out bridge plate.

6. Details of the following if not incorporated into door submittals:

   a. Bridge plate operator details and drawings
   b. Bridge plate control system
   c. Software design description
   d. Position sensing
   e. Cab and passenger controls
   f. Bridge plate obstruction detection
   g. Bridge plate cutout
   h. Warning announcements

6.20 Referenced Standards

The following standards are referenced in this Section:

49 CFR 38 Subpart D	Light Rail Vehicles and Systems
APTA PR-M-S-018-10	Powered Exterior Side Door System Design for New Passenger Cars
IEC 60529	Degrees of Protection Provided by Enclosures (IP Code)

Tilley AR. 2001. The Measure of Man and Woman: Human Factors in Design. Wiley.

END OF SECTION

Table of Contents

Table of Figures

Table of Tables

7.1 General

7.1.1 Scope

This Section includes air comfort systems for the passenger areas and for the Operator's cab.

7.1.2 Power Source

Provide power to the systems in this Section as follows (see Section 9, Electrical Equipment):

1. Air comfort systems: Three-phase ac from the vehicle auxiliary ac inverter.
2. Control systems: DC low-voltage power supply (LVPS).

7.1.3 Quality Requirements

Comply with the following:

1. Quality Control: The equipment manufacturer shall have an ANSI/ASQ/ISO 9001 certified factory quality control program, as a minimum.
2. Manufacturer's Instructions: Comply with manufacturer's instructions for receiving, storing, lifting, installing, and commissioning equipment.
3. Service-Proven: Provide a system and components that meet the requirements for service-proven design, as defined in Section 1, General Topics and Definitions.

7.2 System Design

7.2.1 General

Comply with the following:

1. Provide required capacity in both heating and cooling/dehumidification to bring outside ventilation air and recirculated air to the specified interior temperature.
2. Design in accordance with UL 1995 and ASHRAE Guideline 23.

7.2.2 Calculations

Perform heat loss/heat gain calculations for each interior space.

1. Base calculations upon recognized heating, ventilating, and air conditioning industry criteria.
2. Use actual thermal transmission characteristics of the materials used in vehicle construction.
3. Outdoor ambient temperatures: See the Design Criteria sections for heating and cooling, below.
4. Heating Calculations:
    a. Do not include on-board electrical loads, such as lights.

   b. Assume no passengers.

5. Air Conditioning Calculations:

   a. Include all on-board electrical devices adding heat to the compartment.

   b. Assume AW2 passenger load.

   c. Include solar load, door infiltration load, roadbed load, and other heat loads as recommended in ASHRAE Guideline 23.

6. Assume the adverse effects of exterior solar and wind conditions in all calculations, but assume no beneficial effects due to these outside influences.

7.2.3 Smoke Detection and Alarm

Comply with the following:

1. The HVAC system design, control, and integration into the vehicle shall ensure that the ventilation equipment does not contribute to the lethality of a fire.

2. Provide a manual emergency shutdown mushroom switch on the console.

3. Each vehicle shall have smoke detectors installed in the passenger compartments and, if required, in other areas of the vehicle.

4. The detectors shall be powered from the LVPS and shall be rugged, reliable, and vandal proof.

5. Detectors shall be compliant with NFPA and UL standards.

6. The detectors shall not be sensitive enough to detect cigarette smoke but shall detect smoke in such a concentration that can be considered a threat to passenger safety.

7. When an unsafe condition is detected, the ventilation system on the vehicle shall shut down, close the fresh air dampers, and activate an audible alarm in the cab and a visual indicator on the TOD. The audible alarm in the cab shall remain on until acknowledged, and the visual indicator on the TOD shall remain on until the detector is reset locally.

8. The smoke system unsafe status shall be recorded in the vehicle-level diagnostic system, as shall Operator acknowledgement and the local resetting of the detector.

9. Reset and press-to-test switches shall be in an **approved** location that is accessible to the crew and maintenance personnel and not visible to passengers.

10. Submit details of the design, operation, installation, and testing of the alarm feature for **approval**.

11. The HVAC system shall be included in the fire safety analysis specified in Section 16, Materials and Workmanship, and shall comply with the flammability, smoke emission, and toxicity requirements of Section 16.

7.3 Unitized Package

7.3.1 HVAC Units

Provide HVAC in independent unitized packages (“HVAC units”) containing heating, ventilating, and air cooling components, and related controls:

1. Location: Roof of the vehicle.
2. Rapid removal:
    a. Unit shall be attached using bolted fasteners and multi-pin electrical connectors only; no refrigerant circuit connections shall be required.
    b. The HVAC units (air inlets, air outlets, and drain connections) shall seal directly and automatically to the vehicle using **approved** bulb-type compression seals.
    c. Flexible copper ground straps shall electrically connect the HVAC units to the vehicle-body structure.
3. Quantity: Minimum one HVAC unit for each vehicle body section, with independent temperature regulation for each body section. Small articulation sections do not require dedicated HVAC units.
4. Independence: Failures in one HVAC unit shall not affect operation of the other units.
5. Communication link: Provide between all HVAC units such that adjacent HVAC unit may control the other mechanically-operable HVAC unit in the event of individual controller failure.
6. Lifting:
    a. Provide HVAC units with lifting lugs.
    b. Furnish specifically-designed lifting fixtures for the HVAC units in accordance with Section 19, System Support, as special tools.
    c. If spreader bars or other special provisions are required for lifting, ensure that the lifting fixture cannot be inadvertently installed incorrectly by providing keying and appropriate labeling.
7. HVAC unit storage frames:
    a. Furnish in accordance with Section 19, System Support, as special tools.
    b. Storage frames shall have space for stacking HVAC units at least three high and allow for easy insertion and removal.
    c. Design shall be such that it is not necessary to remove the already stacked units in order to access the bottom unit.
8. Alternative HVAC arrangements may be proposed.

7.3.2 HVAC Enclosure

Provide HVAC enclosure including the following elements and meeting the specified requirements:

1. Frame: Stainless steel 304 or 304L.
2. Cover:
   a. Material: Same as frame, or composite material. Composite materials, where used in weather-exposed conditions, shall have appropriate UV inhibitors against break down in ambient sunlight sufficient for a 30-year life.
   b. Strength: Horizontal covers shall be capable of withstanding, without damage or permanent deformation, the loads from a 95th percentile male walking on the cover with a 12 kg (25 lb) toolbox.
   c. Design: Hinged-type that allows open access to all serviceable parts.
   d. Walkway: Horizontal top access covers of HVAC units shall serve as a walkway for maintenance personnel and shall have **approved** anti-skid provision.
3. Condensate Drainage:
   a. Drain pans:
      - Material: Stainless steel.
      - Design: Such that water cannot spill over into the ceiling area under any operating conditions, including the worst-case combination of negative evaporator section pressure, grade, superelevation, acceleration (positive or negative), and vehicle roll.
      - Mounting: Such that inspection and cleaning of evaporator coils can be performed.
   b. Vehicle-body drain lines:
      - Condensate shall drain through interior vehicle-body piping to the vehicle underfloor, or may drain onto the vehicle roof into dedicated pathways to the roof drains.
      - Drain lines shall comply with the following:
        - Shall be sloped for positive drainage to the underside of the vehicle
        - Shall not be routed through electrical or electronic cabinets
        - Shall not discharge on vehicle structure, equipment enclosures, wheels, or brake equipment
        - Shall be arranged to eliminate any potential water traps
      - Underfloor drain line termination:
        - An elastomeric flapper valve or Kazoo shall be attached to the drain line termination underneath the vehicle
        - Condensate shall not splash on any undercar equipment under any operating conditions

c. Insulation: Drain lines, coil housing, and drain pan shall be insulated to prevent condensation formation.

d. Connection between drain pan and vehicle-body drain lines:

- Connect with heavy gauge flexible tubing, meeting the smoke and flammability requirements of Section 16, Materials and Workmanship.
- Provide clear access to the connections from the interior of the vehicle or equipment bay to allow for unit removal.
- An automatic, self-sealing arrangement may be proposed for connecting the drain pan to vehicle-body drain lines, subject to **approval**.

4. Gaskets: Unit access panels shall be fully gasketed with bulb-type seals to prevent ingress of rain and snow. The use of flat foam strips is prohibited.

7.4 Air Distribution

7.4.1 General

Provide an air distribution system throughout the vehicle:

1. Design: Based upon temperature uniformity requirements in the Temperature Variation section, below.
2. Air quantities: Sufficient to produce heating and cooling capacities calculated for vehicle interior spaces.

7.4.2 Ducts and Diffusers

Convey supply air and return air through dedicated and sealed duct work:

1. Main air distribution ducts:
    a. Location: In vehicle ceiling.
    b. Insulation: Suitable to minimize noise, heat transfer through ducts and roof by direct conduction, and formation of condensation.
    c. Material: Non-flammable.
    d. Maintainability: Ensure all areas are accessible to be cleaned.
2. Air leakage: Maximum 5%, by volume, when measured at 20° C (68° F).
3. Supply air:
    a. Deliver to both sides of vehicle at ceiling level through continuous slot diffusers.
    b. The maximum velocity of discharged air shall comply with ASHRAE Guideline 23.

4. Diffusers:

    a. Material: Anodized aluminum, unpainted, with satin finish.

    b. Design: Shall ensure rapid mixing of ducted air and vehicle air.

    c. Adjustability: Shall be adjustable by the vehicle manufacturer only, to permit adjustment of the airflow balance to maintain temperature differences within specified limits throughout vehicle interior.

5. Return air:

    a. Convey from the passenger area through ceiling return air grilles and dedicated ducts of the shortest possible length to HVAC unit.

    b. Grille:

        - Material: Anodized aluminum frame with satin-finish
        - Construction:
            - Sturdy and rattle-free
            - Sight-tight core from inside the vehicle
            - Hinged on one side with safety catches
        - Keying: See Section 14, Interior and Exterior Appointments

6. Alternate air distribution methods may be proposed.

7.4.3 Air Filters

Provide air filters for fresh and return air to remove airborne dirt, lint, and other fibrous material:

1. Design:

    a. Minimum rating of MERV 13 or higher in accordance with ASHRAE Standard 52.2.

    b. Shall conform to UL 900 and shall not ignite when exposed to a lit cigarette.

2. Access and replacement: From inside the vehicle via a single cover opening or removal using common hand tools.

3. Size: Commercial size readily available from multiple manufacturers.

4. Frames:

    a. Dust-tight, readily accessible, and designed to accommodate both disposable cardboard-frame filters and metal-frame washable filters.

    b. Frames shall support filter elements to prevent blowout of filter elements under clogged conditions.

5. Filter type: 50 mm (2 inch) thick, pleated media, disposable cardboard frame.

6. Face velocity: Not to exceed filter manufacturer's recommendation.

7. Antiviral air treatment: Propose technology to provide anti-viral air treatment.

7.5 Controls

7.5.1 Control Functions

Provide controls to accomplish the following:

1. Automatically activate appropriate operating modes.

2. Achieve specified temperature and humidity inside the vehicle depending on ambient and vehicle interior conditions and variable passenger and solar loads.

3. Achieve safe operation by interlocking the blower fan contactor, overhead heat contactors, and the air conditioning compressor motor contactor to prevent heater or compressor actuation unless the blower fans are energized.

4. During emergency conditions, the fresh air intakes on all HVAC units shall close and the HVAC units shall shut down. Ventilation control used as smoke and fire protection shall override all other control of the ventilation system.

5. Control operation through line gaps to ensure acceptable compressor restart operation after encountering gaps, while maximizing the available cooling. Compressor cycling shall be recorded.

6. Achieve motor protection through a soft-start provision for all motors of the HVAC units to limit the load at start-up. Provide refrigerant compressor and evaporator capacity modulation for temperature and humidity control and to minimize "short-cycling" of the equipment.

7. Coordinate HVAC control with the Hotel Load timer and Auxiliary On/Off switch as specified in Section 5, Operator's Cab Controls.

    a. When operating in cooling mode, after the expiration of the shut-down time delay, the HVAC system shall initiate a pump-down, and perform an orderly shutdown sequence.

    b. The auxiliary power units shall not be allowed to shut down until all HVAC units have completed their shutdown sequence.

7.5.2 Pump Down

Comply with the following:

1. Provide an automatic pump down circuit to reduce the possibility of refrigerant migration during off cycles.

2. Provide pump-down at start-up (or bump-start) for compressor protection after extended off cycles or for periods where pump-down did not occur.

7.5.3 Controllers

Control HVAC functions using microprocessor-based control logic units:

1. Design requirements: Comply with Section 2, Design and Performance Criteria, and with Section 17, Controls, Networks, and MDS.

2. Control logic units:

    a. Enclosure:

        - Provide a single, rugged, totally enclosed sheet-metal enclosure.
        - Provide external cooling fins arranged to avoid the collection of dirt for heat dissipation.
        - Arrange for quick removal and replacement with not more than four captive fasteners.

    b. Electrical connections shall comply with requirements for cable connections to boxes and enclosures in Section 16, Materials and Workmanship.

    c. Provide a PTU connection point, as specified in Section 17, Controls, Networks, and MDS.

    d. Provide power from the vehicle LVPS through a dedicated circuit breaker.

3. Network:

    a. Comply with Section 17. Link control logic units to the vehicle's data network, and provide warnings, status, and diagnostics information to the network and MDS.

    b. All HVAC control units on a vehicle shall be able to exchange temperature and other relevant information to synchronize operation modes. Unit start-ups shall be staggered so that no two units start at the same time.

    c. In case of network communication failure, all HVAC control units shall operate independently.

4. Controls:

    a. All faults shall be logged in the MDS.

    b. Provide with status and fault indication displays, and locate for convenient observation by maintenance personnel.

    c. Provide a fault indication display for each HVAC unit that includes faults for all modes of heating and cooling operation as well as faults for each electronic device of the HVAC unit.

    d. The display shall indicate the status of the following functions as a minimum:

        - Compressors Operating
        - Cooling Mode (full or partial/modulated)
        - Overhead Heat, including staging or PWM percentage or both
        - Floor Heat (each stage, as applicable)

- Floor Heat Ground Fault Trip (each stage, as applicable)
- High/Low Pressure Trip and Lockout
- Overheat Devices Trip and Lockout
- Hot Vehicle
- Cold Vehicle
- Low Airflow
- Temperature Sensors (return air, fresh air, and supply air temperature)
- Smoke Detector(s)
- Fresh Air Damper Status
- Ventilation Mode
- Windshield Heater
- Threshold Heater
- Overcurrent (all motors)
- General Fault

5. The controls shall ensure the following:

    a. That HVAC control logic unit shutdown and restart occurs in a safe and predictable manner.

    b. That spurious faults or lockouts are not generated during shutdown, restart, or during periods of power loss.

    c. That stored diagnostic data is not lost during shutdown or restart.

    d. That time-stamp integrity is maintained on all diagnostic data through each shutdown and restart process, including immediately after restart.

6. All power interruptions likely to have corrupted temporary storage shall be detected and cause the system to re-initialize all affected routines and temporary data. Detection of power interruptions may be by hardware.

7. Fault criteria for triggering faults and system response, including number of cycles to equipment lockout, shall be evaluated during qualification testing:

    a. Where tests may result in damage to the system hardware, the fault or event may be simulated to avoid damage to the hardware.

    b. Tests shall be performed on a complete HVAC unit or HVAC system or both any time the software is changed prior to putting it into service.

7.5.4 Temperature Sensors

The heating and air conditioning control system shall obtain temperature information by means of thermistor sensors in the return, fresh, and supply air streams.

1. The thermistors shall be encapsulated in a protective stainless steel tube.
2. The layover thermostat may be a rail-service-proven bimetallic type with set points as specified.
3. Provide humidity control using cooling with modulated reheat, or cooling alone, as required to maintain the proper interior temperature and humidity. The use of a humidistat may be proposed.
4. Temperature sensors shall be mounted to ensure the following:
   a. They are not unduly influenced by local sources of heat, such as motors or resistors.
   b. They are not unduly influenced by solar radiation.
   c. They are easily accessible for maintenance and replacement.
   d. They are protected from damage during routine air conditioning servicing, such as replacing filters.
   e. They are not unduly influenced by adjacent air streams.
   f. They do not present a safety hazard to maintenance personnel.
5. The fresh air sensor(s) shall not be unduly influenced by a layover condition.
6. Sensor accuracy shall be sufficient to comply with the requirements of the Specifications.
7. Provide a duct temperature control sensor. The controls shall compare the duct sensor reading with the return air sensor reading and, using a PI or PID control algorithm, maintain supply-air temperature at or not more than 2.8° C (5° F) above the sensed return-air temperature under stabilized conditions when cooling is not required.

7.5.5 Temperature Variation

Vehicle interior temperatures shall comply with the temperature variation guidelines for urban vehicles in ASHRAE Guideline 23.

7.5.6 Overhead Heat Control

Comply with the following:

1. Provide control circuitry to accomplish the following:
   a. Temper the incoming fresh air. Overhead heat may be used, upon **approval**, to partially regulate the required heat to the interior space.
   b. Prevent damage from excessive heat buildup in the heating element plenum, such as may occur with loss of air flow.

2. As a minimum, provide the following sensors and controller functions:

   a. Heater duty cycle: Regulate to meet control parameters corresponding to interior temperature requirements stated below in the Heating Temperatures section.

   b. Air flow: Switch off overhead heat without sufficient air flow acknowledged by the controller.

   c. High-limit temperature sensors: Provide adjacent to each overhead heater unit to detect excessive temperature:

      - Upon detection of excessive temperature by either sensor, heater shall switch off and send an indication to controller and TOD.
      - If temperature cools below lower limit at both sensors, heater may switch on automatically.

   d. Back-up protection device: Provide in addition to the heater circuit breaker, to remove power in the event of excessive current draw or excessive heat:

      - The device shall be a bimetallic-type thermal cutout, shunt trip, or **approved** equal, in the power line to the overhead heating elements. Fusible links are prohibited.
      - The device shall be replaceable in no more than 1 hours' time.

   e. In the event of a controller failure, the heating elements shall fail in the power-off condition.

7.5.7 Floor Heat Control

Provide controls to modulate floor heat and avoid temperature fluctuations in the passenger area.

7.5.8 HVAC Layover Mode

Provide an HVAC layover mode for both the passenger and cab areas:

1. Temperature settings:

   a. Non-adjustable.

   b. Layover heat: Maintain average temperature at 7° C +/- 3° C (45° F +/- 5° F) with the HVAC unit controls powered off, controlled by a bimetallic thermostat(s) installed in an **approved** location within the vehicle.

   c. Layover air conditioning: Maintain average temperature at 26° C +/- 3° C (79° F +/- 5° F).

2. Activation: Automatic when the Hotel Load timer expires, as specified in Section 5, Operator's Cab Controls.

7.6 Heating

7.6.1 General

Provide thermostatically controlled electrical heating using overhead and floor heat.

7.6.2 Heating Design Criteria

Design the system based on the following winter conditions:

TABLE 7-1, HEATING DESIGN CRITERIA	
Heating Design Ambient Temperature	-10° C DB (14° F DB)
Passenger Load:	None
Solar Load:	None
Heating Load:	None

7.6.3 Heating Temperatures

Comply with the following:

1. Heating capacity:
   a. Sufficient to maintain heating interior temperature within the range specified below.
   b. Sufficient without reliance on passenger heat contribution or solar loading as heat sources.
2. Heating interior temperature range: In accordance with Figure 7-1, Temperature Setpoint Chart, below.
3. Heating equipment surface temperature: Maximum 52° C (125° F) where exposed to passengers or Operator, under all operating conditions.

7.6.4 Overhead Heat

Incorporate heating elements into HVAC units:

1. Capacity: Sufficient to temper outside fresh air to required vehicle interior temperature for all heating conditions, as a minimum, and to compensate for the deficiency of floor-heater capacity if floor heaters cannot fully compensate for the vehicle-body heat loss due to lack of space.
2. Reheat function: Use overhead heating elements to provide reheat for dehumidification and cooling offset at conditions lower than design cooling conditions.

7.6.5 Floor Heat

Provide floor heat using baseboard convection units. The use of forced air heating units may be proposed:

1. Capacity:
   a. Sufficient to compensate for vehicle-body heat loss through conduction and radiation at the heating design conditions without consideration of any internal vehicle heat sources or heat from passengers, and with the ventilating fans/overhead heat from the HVAC units inoperative.

   b. If every wall space suitable for floor heat has been used and floor heat capacity is still insufficient to compensate for vehicle-body losses, overhead heat may be used to supplement floor heat upon **approval**.

2. Location: Mount along the sidewalls at the floor.

3. Type:

   a. Electric strip or tube type heaters mounted behind heater guards.

   b. Heater elements shall be mounted on insulators mounted to the vehicle body, not to the heater guards.

   c. No more than two types of floor heating elements are permitted.

4. Heater guards:

   a. Material: Non-denting stainless steel or coated-aluminum.

   b. Design: Sloped to prevent the accumulation of debris.

   c. Front sections:

      - Constructed so that sections may be easily removed for replacement of heating elements without dismantling seats, adjacent heater guards, or other fixed appurtenances.

      - Fasteners: Reusable screws. Self-tapping screws are prohibited.

   d. Lower sections: Constructed to prevent the accumulation of dirt.

   e. Grounding: Independently ground heater guards to the vehicle body, with each guard using a single ground point and ground strap.

   f. Surface temperature of heater guards: Maximum 52° C (125° F) in their installed configuration.

5. Heater wiring:

   a. Wire insulation:

      - Rated 150° C.

      - Arranged such that electrically "live" points cannot be reached if an object, such as a knife or screwdriver blade, is inserted through the holes in the heater guard face.

   b. Terminal connections:

      - Accessible to maintenance personnel but not passengers through an access panel.

      - Covered with a protective boot rated for high temperature.

6. Electrical protection:

   a. Protect each floor heater circuit with a ground fault interrupting device.

b. The ground fault circuit shall remain latched in the disconnected mode (no power to the unit) until manually reset by means of a momentary reset button.

c. The fault trip shall not be affected by control power loss or fluctuations.

d. A tripped ground fault circuit shall be annunciated on the TOD and by an LED indicator for each stage on the ground fault detection device in the HVAC control logic unit.

e. The sensor device shall be designed such that it is not necessary to disconnect heater power leads to remove and replace the ground fault detection unit.

7.6.6 Threshold Heaters

Provide each exterior doorway with a protective heating system:

1. Design to prevent freezing in the threshold area whenever the exterior ambient air temperature is below 4.4° C (40° F).
2. Cable and electrical terminations shall be environmentally sealed to withstand exposure to cleaning chemicals, deicing salts, brine, etc., present in the door area.
3. The system shall operate whenever a Master Controller key switch is used to activate the vehicle or when the vehicle is in layover mode, and a control signal from the HVAC control system indicates that the ambient temperature is below 4.4° C (40° F). It shall also operate whenever the layover heating system is in operation.
4. No heated surface that could be contacted by a passenger or be in contact with any nonmetallic door seal or guide shall exceed a temperature of 51.7° C (125° F).
5. Provide access to all electrical terminations for maintenance.
6. The threshold heater system shall be as **approved**.

7.7 Ventilation

Provide ventilation of each vehicle-body section of the vehicle, as part of the HVAC unit, using the air conditioning system evaporator unit blower fans:

1. Full ventilation: Continuously available if cooling or heating apparatus fails.
2. Air distribution: By ducts and diffusers.
3. Ventilation rate: In accordance with ASHRAE Guideline 23 for urban service with an AW2 passenger load.
4. Fresh air intakes:

   a. Provide on HVAC units.

   b. The fresh air intake duct shall be designed to preclude the entrance of wind driven snow and rain and shall be sloped to drain any moisture that may enter the ducts to the outside of the vehicle. The duct shall be arranged such that no water traps can exist.

c. Water eliminating baffles or louvers: Provide within the fresh air intakes to prevent water that enters the fresh air intakes from being drawn into the HVAC unit:

- Material: Stainless steel or anodized aluminum.
- Maintainability:
  - Shall be easily removable for cleaning and servicing from inside the vehicle.
  - Cleaning and servicing of water eliminators shall not be required more frequently than once a year without any significant reduction in the system performance.
- Fresh air filters shall not be considered part of the water elimination design and under all conditions shall not become wet.

d. Motorized fresh air damper assemblies: Provide at each fresh air intake:

- Type: Energized-open spring-closed design, service-proven. A Direct Control Ventilation (DCV) design based on passenger loading may be proposed.
- Material: Stainless steel.
- Maintainability: Readily accessible for routine cleaning from inside the vehicle through the return air grille.
- Dampers shall close for the following:
  - Emergency shutdown
  - To expedite pull-up and pull-down of the vehicle interior temperature.
  - Vehicle is in vehicle wash mode

5. Internal static pressure: Positive at all vehicle speeds, minimum 25 Pa (0.1 inches of water) within a closed or stopped vehicle.

6. The design of the ductwork shall consider the combination of air velocity, capacity, acoustic insulation, shape, and diffuser design, to ensure compliance with the interior noise and vibration requirements (see Section 2, Design and Performance Criteria).

7. Exhaust: Provide for adjusting the airflow from HVAC units.

8. Fresh air inlets/exhaust:

a. Material: Stainless steel

b. Maintainability: Easily accessible for routine maintenance and cleaning from the side of the vehicle (at roof level) and from within the mixing plenum chamber.

c. Protection:

- Shall prevent the ingestion of foreign particles, ice, and water into the ventilation system.
- Shall prevent the inlets from being blocked by ice or snow accumulation that would interfere with the proper operation of the environmental systems or any equipment of the systems on the vehicle.

- The ductwork design shall incorporate features that prevent the ingress of water into the vehicle or the vehicle-body structure.
- Fresh air filters shall not be considered as part of the water/snow elimination design.

9. Evaporator Unit Blower Fans:

   a. Type: Direct driven, integral to the HVAC unit. A single- or double-fan arrangement may be used.

   b. Operation:

      - Fans shall blow or draw the mixed air through the evaporator coils and force it into a supply air plenum from where it is discharged through diffusers into the passenger and cab areas.
      - Coil face air velocity through the evaporator coil shall be limited to prevent condensate carry**over into the fan plenum or main duct.**

   c. Drive motors:

      - Totally enclosed with permanently lubricated rolling element bearings.
      - Designed for transit-vehicle application and available from multiple suppliers, with at least one North American supplier.
      - Suitable for continuous duty with the maximum temperature rise within the HVAC unit due to solar radiation, overhead heat, and other factors.
      - Fitted with an **approved** insulated bearing system to prevent harmful circulating harmonic currents through the bearings.

   d. Blowers: Heavy-duty construction that does not exhibit imbalance/vibration due to normal handling, dirt buildup between scheduled maintenance, and cleaning, including dismantling and reinstallation.

   e. Power: Blower units shall operate from ac power provided by the onboard auxiliary ac inverter.

   f. Grounding: Provide a flexible safety ground strap from the motor frame to the grounded HVAC unit structure.

   g. Motor/blower assembly balancing and isolation:

      - Shall be balanced according to ANSI/AMCA 204.
      - Imbalance shall be less than 0.001 inch peak-to-peak displacement in any direction at the motor end-bells when mounted in the HVAC unit.
      - Shall be isolated such that motor and fan vibration and noise transmitted to the vehicle structure is below the limits specified in Section 2, Design and Performance Criteria.

7.8 Air Conditioning

7.8.1 General

Provide cooling and dehumidification as part of each HVAC unit:

1. Capacity: Adequate to produce the required interior temperatures and humidity throughout the entire range of operating conditions.

2. Type: Vapor-compression direct-expansion refrigeration cycle.

7.8.2 Cooling Design Criteria

Design the system based on the following summer conditions:

TABLE 7-2, COOLING DESIGN CRITERIA	
Cooling Design Ambient Temperatures	34.5° C DB (94° F DB) 24° C WB (75° F WB)
Maximum Operating Conditions	46° C DB (114° F DB) 27° C WB (80° F WB)
High Temperature Operating Conditions	51° C DB (124° F DB) 28° C WB (82° F WB)
Passenger Load:	450 Btu/h per passenger at 55% Sensible Heat Ratio
Solar Load:	Follow ASHRAE Guideline 23 recommendations
Heating Load:	Total wattage of interior lights and vehicle equipment
Vehicle-Body Heat Transmission	In accordance with the Contractor’s vehicle-body and insulation design and ASHRAE Guideline 23

7.8.3 Cooling System

Comply with the following:

1. Cooling capacity:

    a. Sufficient to maintain cooling interior temperature as specified below.

    b. Conditions:

    - AW2 passenger load
    - Maximum solar load based on worst case sun position and vehicle orientation
    - Door infiltration load, roadbed load, and any other heat load as recommended in ASHRAE Guideline 23.

2. System design:

   a. Shall allow full cooling operation without the influence of modulation control with the ambient temperature up to Maximum Operating Conditions at the condenser and fresh air intakes (see Cooling Design Criteria, above).

   b. System shall be capable of operation, at reduced capacity if necessary, up to High Temperature Operating Conditions with design internal and solar loads (see Cooling Design Criteria, above).

3. Supply Airflow: Sufficient to meet the internal temperature, humidity, and vehicle pressurization requirements without exceeding the maximum air velocity requirements.

4. The cooling system shall be able to start and operate without damage at any time of the year when the exterior temperature is above 7° C (45° F).

7.8.4 Cooling Temperatures and Humidity

Cooling interior temperature, including the cab, shall be in accordance with Figure 7-1, Temperature Setpoint Chart, below:

1. When the net heating or cooling power required is within the capacity of the system, the system shall maintain the average temperature inside the vehicle within 0.8° C (1.5° F) of the setpoint.

2. When the net heating or cooling power required exceeds the available capacity of the system, the setpoint shall be maintained, but the interior temperature shall be allowed to deviate from the setpoint in proportion to the difference between the available heating or cooling power and the net heating or cooling power required.

3. When cooling is required at or below design conditions of this Section, the interior relative humidity shall be within the comfort zone limits as defined by ASHRAE Standard 55.

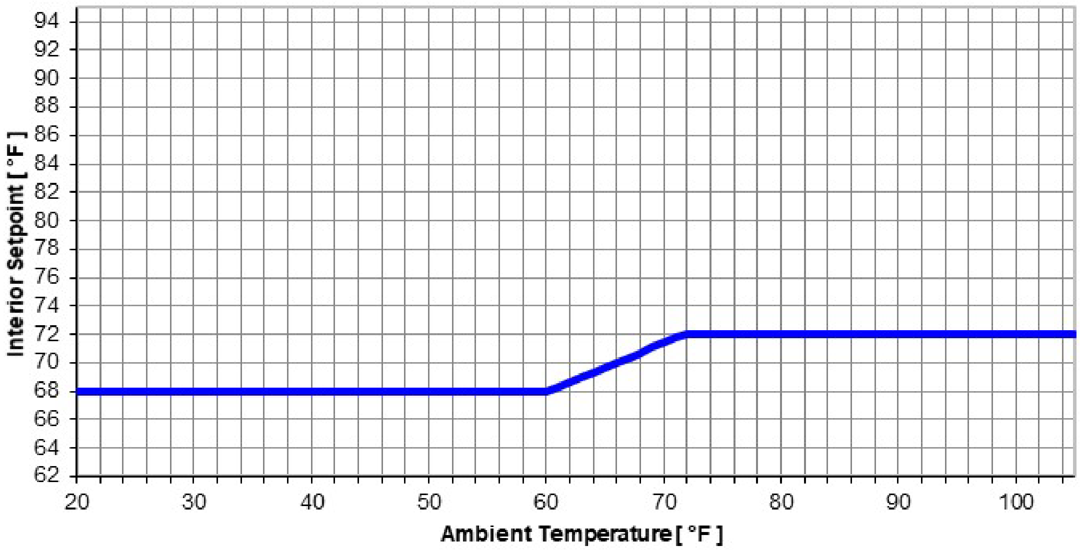


FIGURE 7-1, TEMPERATURE SETPOINT CHART

7.8.5 Refrigerant

The refrigerant shall be listed on the U.S. EPA SNAP list for Motor Vehicle Air Conditioners for Passenger Air Conditioning in Buses and Trains, with an ASHRAE Safety Rating of not less than A1 and comply with current environmental regulations governing refrigerant use, handling, and recovery. The refrigerant is subject to **approval**.

7.8.6 Compressors

Refrigerant compressors shall comply with specified requirements and include each listed item:

1. Type: Hermetically sealed, scroll type design, transit service proven.
2. Power: Three-phase ac.
3. Capacity control:
    a. Include a balance-ported thermo-expansion valve (for each evaporator circuit), and compressor capacity control, whether single-circuit or multi-circuit units are provided. A fixed-orifice design may be proposed for the modulation of the evaporator coil.
    b. Variable speed compressor control may be proposed. If multiple compressors are provided for capacity control, means to equalize the usage of the compressors over time shall be provided.
4. Crankcase heaters and a suction line replaceable strainer.
5. A suction line accumulator (as recommended by the compressor manufacturer).

7.8.7 Evaporators and Condensers

Comply with the following requirements for heat exchanger coils:

1. Material: Copper tubing, copper or corrosion resistant aluminum fins.
2. Fin spacing: Adequate to facilitate cleaning in transit vehicle service conditions. Furnish a cleaning procedure and demonstrate that the fins can be cleaned easily using biodegradable detergent and rinsing with water.
3. Fin strength: Capable of withstanding 175 kPa (25 psi) water or air pressure from a cleaning wand.
4. Fin thickness: Minimum 0.2 mm (0.008 in). If less than the minimum thickness is proposed, demonstrate fin/coating strength and longevity by a salt spray test according to ASTM B117 or ISO 9227 and by similar rail transit reliability data.
5. Coil tube sheets: Die-formed support collars for each tube. Where coil tubing connects to the inlet/outlet header, the tube support sheets shall include a provision to prevent chafing of the tubes against the end plates during expansion/contraction.
6. The evaporator coil shall contain two interlaced circuits for capacity modulation.
7. The condenser coil shall be designed with adequate capacity to keep the system in full cooling when obstructed 15% and at the extreme operating points specified with full internal loading.

7.8.8 Condenser Fan-Motor Assembly

Provide a condenser fan-motor assembly(s) for condenser coil capacity control:

1. Each condenser motor-fan assembly shall be balanced according to ANSI/AMCA 204. Imbalance shall be less than 0.002 inch peak-to-peak displacement in any direction at the motor end bells when mounted in the HVAC unit.
2. The condenser motor assembly shall be isolated such that motor and fan vibration and noise transmitted to the vehicle structure is below the limits specified in Section 2, Design and Performance Criteria.
3. Condenser fans and shall be easily removable without having to remove an entire condenser fan motor assembly.
4. Metallic condenser fans shall be coated to prevent corrosion.
5. Provide a protective grille above the condenser fan(s). The condenser fan grille(s) shall be mounted as part of the HVAC unit structure, such that finger protection continues to be in place if the condenser cover(s) is opened.

7.8.9 HVAC System Devices

Provide the following:

1. Filter-drier:
   a. Replaceable “catch-all” type.
   b. The filter dryer capacity of water, refrigerant flow, filtering area, and acid removal shall be specified based on AHRI Standard 710 (I-P).
   c. The filter drier shall have rustproof shutoff valves on each side to isolate it for servicing. Provide an access fitting on one valve to allow recovery and evacuation of the filter drier section.
2. Sight glass with moisture indicator: Provide in refrigerant liquid lines.
3. Pressure relief device: To protect the refrigeration system against explosion. Comply with ASHRAE 15, and applicable requirements of UL 1995 and UL 207.
4. Schrader valves:
   a. Location: External, to connect pressure gauges while unit is running.
   b. Type: Self-sealing, with chain-retained, metal-to-metal seal caps.
5. Pressure switches:
   a. Provide safety switches for low and high pressure.
   b. Switches shall stop the compressor motor upon a loss of refrigerant or excessively low or high system pressures that could damage the HVAC unit.
   c. The high- and low-pressure safety switches shall be wired directly in the refrigerant compressor-motor power-switching device control circuit.
   d. The switches shall be connected to a common pressure manifold through 1/4-inch SAE flare connections with internal Schrader valves.
   e. The pressure switches shall be color coded and arranged such that they cannot be interchanged with any other pressure device or installed into the incorrect port of the pressure manifold.
6. Pressure Transducers:
   a. Pressure transducers shall be used to regulate the system capacity control.
   b. Low-pressure transducers shall stop the refrigerant compressors when the system pump-down pressure is reached.
   c. High-pressure transducers shall stop the refrigerant compressors when the pressure is approaching the setting of the high-pressure cutout switch. The software shall detect an abnormal frequency of short run-times and preclude the affected system from restarting until serviced.

d. Pressure transducers shall be connected to a common pressure manifold through 1/4-inch SAE flare connections with internal Schrader valves.

e. The pressure transducers shall be color coded and arranged such that they cannot be interchanged with any other pressure devices or installed into the incorrect port of the pressure manifold.

7.8.10 Air Conditioning System Piping and Fittings

7.8.10.1 Layout and Design

Comply with the following requirements:

1. Design tubing installations such that a single length of tubing may be replaced without dismantling or removing surrounding equipment, piping, wiring or other appurtenances.

2. Keep joints to a minimum with no inaccessible joints or fittings; inaccessible runs of tubing shall be without joints.

3. Provide suction lines without traps. Size the liquid line adequately to prevent flashing due to pressure drop.

4. Mount and support copper piping such that shock and vibration do not cause failure of solder joints. Provide vibration eliminators in piping connections to the compressor. Equipment and piping shall meet the criteria of IEC 61373.

7.8.10.2 Type

Comply with the following standards:

1. Air conditioning refrigerant lines: Per ASTM B280 or ASTM B88 type L, seamless copper tubing or **approved** stainless steel tubing. Fittings shall be wrought copper sweat type.

2. Condensate drain lines: Seamless copper tubing, ASTM B88 type K or A.

3. Comply with Section 16, Materials and Workmanship.

7.8.10.3 Fabrication

Comply with the following fabrication requirements:

1. Tubing may be bent only with an appropriate tube bending tool.

2. Deburr piping after cutting and thoroughly clean after installation.

3. After pre-fabrication, clean piping and pipe subassemblies, dry (if required), and cap all openings.

4. Caps shall remain in place until immediately prior to incorporation into the final assembly.

7.8.10.4 Refrigerant Line Soldering

Comply with the following soldering requirements:

1. Soldering of copper piping and fittings: Perform to AWS A5.8M/A5.8.
2. Refrigerant pressure piping filler metal:
    a. Silver content: Minimum 15% for copper-to-copper joints; between 35% and 45% for dissimilar metal joints.
    b. Cadmium free.
3. Non-pressure copper lines silver content: Minimum 15%.
4. Comply with Section 16, Materials and Workmanship.

7.8.10.5 Insulation

Insulate lines and refrigerant components subject to condensation forming:

1. Insulate condensate drain lines and suction line piping with insulation that meets the flammability, smoke emission, and toxicity requirements of Section 16, Materials and Workmanship.
2. Insulate the liquid line in all areas where required to give additional mechanical or thermal protection.
3. Apply the insulating material to the piping with suitable contact cement.
4. Miter and seal joints and directional changes in the insulation.

7.8.11 Air Conditioning System Charging and Testing

Charge and test each self-contained air conditioning unit at the factory before shipping:

1. Perform leak testing, evacuation, and charging to the manufacturer's own procedure, but as a minimum incorporate the following steps:
    a. Leak test per **approved** procedure.
    b. Evacuate and dehydrate the entire refrigeration system to a pressure of 100 microns of mercury, or less.
    c. Maintain this vacuum level for minimum two hours with the vacuum pump running.
    d. After two hours, isolate the vacuum pump from the system.
        - The system pressure should not rise above 300 microns of Mercury in a two-hour period after vacuum pump isolation
        - Decay in the vacuum indicates that moisture remains in the system, or a leak
        - Measure vacuum levels at the system, not at the entrance to the vacuum pump

e. Charge with the predetermined amount of refrigerant by weight.

2. Factory testing shall include air conditioning unit routine tests specified in Section 15, Testing.

7.9 Operator’s Cab Air Comfort System

7.9.1 General

Provide heating, cooling, and defrosting/defogging in each cab as specified below.

1. Provide conditioned air into the cab from a dedicated HVAC unit, as specified below. If the cab unit fails, conditioned air from the passenger area shall automatically be supplied to the cab with no action from the Operator.
2. Provide cab HVAC in independent unitized packages (“HVAC units”) containing heating, ventilating, and air cooling components, and related controls.

7.9.2 Cab Heaters

7.9.2.1 General

Provide one or two identical forced-air cab heaters for defrosting and heat in each Operator’s cab.

7.9.2.2 Cab Heater Housing, Ducting, and Vents

Provide listed components and comply with the following requirements:

1. Heater housing:
   a. Material: Heat-resistant, nonflammable
   b. Configuration: Fully enclose the heater elements.
   c. Surface temperature: Maximum 52° C (125° F) under all operating conditions, where exposed to operating personnel.
2. High limit thermostat: Provide in the heater housing to remove power in the event of excessive temperature.
3. Back-up protection device: Provide in the heater housing to remove power if high-limit thermostat fails, to prevent excessive temperature that may cause injury to SEPTA’s personnel, or damage to equipment.
4. Grounding: Permanently ground heater assembly and enclosure to vehicle structure, as specified in Section 9, Electrical Equipment.
5. Ducting and vents:
   a. Direct heater output onto side windows and windshield.
   b. Direct heater output onto the Operator’s feet and provide a manually adjustable damper.

c. Ducting and damper arrangements shall not permit airflow to be blocked to the extent that the heater overheats or trips the high-limit thermostat or back-up protection device.

7.9.2.3 Cab Heater Capacity

Comply with the following:

1. Cab heaters shall have capacity adequate to maintain a temperature of minimum 21° C (70° F) in the full-width cab compartment under the following conditions:

    a. Exterior ambient temperature equal to the Heating Design Ambient Temperature in the Heating Design Criteria section, above.

    b. Overhead air diffuser shut-off.

    c. Side windows closed.

2. Provide sufficient capacity to defrost the cab side windows and windshield without aid of the windshield's electrical defrosting heater circuits, using SAE J902 as a guide, as follows:

    a. Time period: Maximum 30 minutes for side windows and the windshield.

    b. Exterior Ambient Temperature: Equal to the Heating Design Ambient Temperature in the Heating Design Criteria section, above.

    c. Condition: Vehicle is activated after being de-energized for a period of 8 hours and exposed to Heating Design Ambient Temperature during that time period.

7.9.2.4 Cab Heater Controls

Comply with the following:

1. Heater functions shall include Auto and at least three stages of heat with appropriate fan speeds for each.

    a. In auto mode the cab heater will communicate with the Cab HVAC-unit temperature controller (ref section 5.8.6) to reach the temperature setpoint of the variable dial. In the case of the cab heater selector switch is placed in one of manual position (three stages) the cab heater will not be controlled by the Cab HVAC-unit temperature controller and the manual stages will be activated.

    b. The fan shall be interlocked with the heating elements such that the elements cannot be energized unless the fan is operating.

    c. The cab HVAC-Unit temperature controller must indicate if the cab heater is operating or off regardless of selector switch position (manual modes or auto mode).

    d. In manual heating operation of the cab heater, no cooling is allowed from the Cab HVAC-unit.

2. Active Cab: Provide control of heaters from the Cab Console, specified in Section 5, Operator's Cab Controls.

3. Inactive cab at opposite end of the train:

    a. Provide low-temperature control independent of the state of the heater control switches on the Cab Console.

    b. Maintain temperatures in inactive cab at 16° C (60° F) via modulation of cab heater controls using temperature sensors in each cab, under the following conditions.

    - Cab inactive (but other cab active)
    - Ambient temperatures below 10° C (50° F)

    c. Provide windshield defrosting and defogging independent of the state of the heater control switches on the Cab Console under the following conditions:

    - Cab inactive (but other cab active)
    - Ambient temperatures below 5° C (41° F)

7.9.3 Cab HVAC Unit

7.9.3.1 General

Provide an independent HVAC unit installed on the roof of each cab. Comply with the requirements above for vehicle HVAC units, but provide temperature regulation in each Operator's cab for the dedicated cab HVAC unit, independent from the adjacent passenger section.

7.9.3.2 Diffusers

Provide adjustable diffusers for the Operator to set air flow and direction:

1. Air flow adjustment range: Include full off.
2. Direction adjustment range: Include the ability to direct air flow away from Operator.

7.9.3.3 Overhead Heat

Incorporate heating elements into the cab HVAC unit. Heating capacity, as a minimum, shall be as required to temper the outside air from the design ambient to design interior condition.

7.9.3.4 Ventilation

Provide ventilation of each cab using the cab air conditioning system evaporator unit blower fans.

1. Full ventilation shall be continuously available if refrigeration fails.
2. The air comfort system shall deliver fresh air to the cab in the amount of minimum 10 l/s (21 ft^3/min).

7.9.3.5 Air Conditioning

Comply with the following:

1. All requirements above for air conditioning for the vehicle passenger sections, including maximum solar load into the cab based on worst case sun position and vehicle orientation.

2. Use same refrigerant as for passenger HVAC units.

7.9.3.6 Cab HVAC Unit Controls

Provide controls in each Operator’s cab for the cab HVAC as specified in Section 5, Operator’s Cab Controls.

7.9.4 Windshield Defrosting and Defogging

Provide electrical defrosting heater circuits embedded in the cab windshield controlled via the Cab Console (see Section 5, Operator’s Cab Controls). See related windshield requirements in Section 14, Interior and Exterior Appointments.

1. The windshield heater system shall have sufficient capacity to defrost and defog the windshield without aid of the cab heater, using SAE J902 as a guide, as follows:

    a. Time period: Maximum 10 minutes.

    b. Exterior Ambient Temperature: Equal to the Heating Design Ambient Temperature in the Heating Design Criteria section, above.

    c. Interior Dew Point: 20° C (68° F).

    d. Condition: Sufficient moisture has condensed to just begin to run down the glass.

2. The windshield heater system shall heat the area where the windshield wipers rest.

3. The heating elements embedded in the windshield shall be two separate circuits interlaced across the entire surface of the windshield and not sectioned. If a heating-element fails, the second circuit shall continue to be available to defrost and defog the entire surface of the windshield at a reduced performance.

4. Exposed heating surface temperature: Maximum 52° C (125° F) under all operating conditions.

7.10 Contract Deliverables Requirements List (CDRL)

7-1 Calculations
7-2 HVAC Unit Design Package
7-3 Air Distribution Design Package
7-4 HVAC Control Design Package
7-5 Floor Heat Design Package
7-6 In-Factory Charging and Testing Booklet
7-7 Operator's Cab Air Comfort System Design Package

7.11 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested
5. Software functional descriptions: Include top level control parameters and values

7-1 Calculations:

1. Include assumptions
2. Heat Loss/Heat Gain
3. Heating and cooling capacity
4. Include both the Operator and passenger cabins and show separately
5. Analysis of energy saving options including but not limited to the use of variable speed motors and variable damper controls.

7-2 HVAC Unit Design Package:

1. HVAC unit arrangement drawing showing the quantity, location, heating/cooling capacity of each unit on the vehicle.
2. Certifying letter of manufacturer's ANSI/ASQ/ISO 9001 certified factory quality control program.
3. Manufacturer's dimensioned layout drawings for all types of HVAC units.
4. Electrical data for all types of HVAC units.
5. Electrical load (or coefficient of performance) for heating and cooling at maximum capacity for each unit on the vehicle.
6. Details of overhead heating.
7. Details of ventilation.
8. Air Conditioning:
    a. Component identification
    b. Materials identification
    c. General layout drawings
    d. Electrical and controls schematic
    e. Piping schematic
    f. Make and model number for compressor, purchased controls, sensors, and instrumentation.
    g. Acceptable charging procedure for the system charged with blended refrigerant.
    h. Heat exchanger coil fin cleaning procedure.

9. Air Conditioning Piping:

    a. Description of all fastening and joining methods for refrigerant piping, including silver solder procedures.
    b. Manufacturer’s data for air conditioning system piping insulation and insulation joint-sealing material.

7-3 Air Distribution Design Package:

1. Airflow velocity calculations for both the Operator and passenger cabins, shown separately
2. Pressure drop calculations.
3. Overhead ductwork and diffuser drawings.
4. Air Filters:

    a. Manufacturer’s data on air filter including brand, type, and size.
    b. Include quantity.

7-4 HVAC Control Design Package:

1. Include the following:

    a. Brand(s), type, and model of microprocessor-based control units or PLC and control devices
    b. Manufacturer’s data on overhead heat back-up protection device used to remove power in the event of excessive current draw. Include the means used to suppress the arc at rupture.

2. Layover Climatic Control:

    a. Manufacturer’s data on components.
    b. Location of the layover thermostat, if a separate thermostat is used.

7-5 Floor Heat Design Package:

1. Design drawings, including details of heating units and layout.
2. Manufacturer’s data on heating elements.

7-6 In-Factory Charging and Testing Booklet:

1. Include one booklet for each self-contained air conditioning unit.
2. Booklet shall contain charging certification and results of air conditioning unit routine tests, as specified in Section 15, Testing.

7-7 Operator’s Cab Air Comfort System Design Package:

1. Description and details of controls
2. Cab HVAC Unit:

    a. Details of overhead heat
    b. Details of ventilation
    c. Air conditioning: Submit all items required for passenger section air conditioning

3. Details of how passenger compartment conditioned air will be supplied to the cab, including the following:

    a. Ducting size and locations
    b. Airflow
    c. Heat gain/loss and verification that airflow is sufficient to maintain specified temperatures

4. Cab Heaters:

    a. Manufacturer's heater details, including the following:

        - Electrical requirements
        - Housing material
        - Automatic high-limit thermostat in the heater housing to remove power in the event of excessive temperature

    b. Layout drawing indicating ducting and vents and showing how heat will be directed for both heat and defrosting
    c. Details of windshield embedded defroster, including controls, temperature limits, and over-temperature protection

7.12 Referenced Standards

The following standards are referenced in this Section:

AHRI Standard 710 (I-P)	Performance Rating of Liquid-Line Driers
ANSI/AMCA 204	Balance Quality and Vibration Levels for Fans
ANSI/ASQ/ISO 9001	Quality Management Systems - Requirements
ASHRAE Standard 15	Safety Standard for Refrigeration Systems
ASHRAE Guideline 23	Guideline for the Design and Application of Heating, Ventilation, and Air-Conditioning Equipment for Passenger Rail Vehicles
ASHRAE Standard 52.2	Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
ASHRAE Standard 55	Thermal Environmental Conditions for Human Occupancy
ASTM B88	Standard Specification for Seamless Copper Water Tube
ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B280	Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
AWS 5.8M/A5.8	Specification for Filler Metals for Brazing and Braze Welding

IEC 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
ISO 9227	Corrosion tests in artificial atmospheres -- Salt spray tests
SAE J902	Passenger Vehicle Windshield Demisting and Defrosting Systems
UL 207	Standard for Refrigerant-Containing Components and Accessories, Nonelectrical
UL 900	Standard for Air Filter Units
UL 1995	Heating and Cooling Equipment
U.S. EPA SNAP list	Substitutes in MVAC: Passenger Air Conditioning in Buses and Trains

END OF SECTION

Table of Contents

Table of Tables

8.1 General

All lighting shall be via LEDs. Except for console and similar small low-intensity indicator lamps, all lamps shall be LED clusters.

Provide lamps with standard dimensions and electrical connections. Lamps, sockets, and connectors are considered consumable items, and shall be commonly stocked and available from U.S. suppliers.

8.2 Lighting System Design

The lighting system design and illumination requirements shall meet the following federal regulations, APTA standards, and other applicable standards for vehicle lighting:

1. 49 CFR 38 Subpart D
2. APTA RT-VIM-S-020-10
3. APTA PR-E-RP-012-99
4. IEEE 1789
5. For exterior lighting, 49 CFR 571.108. Apply requirements for buses of 2032 mm (80 inches) or more in overall width.
6. ANSI and SAE standards, as specified in sections below.

If a conflict exists, the most restrictive requirement shall apply.

8.3 Normal Lighting Levels

Lighting levels specified below shall be achieved at the nominal rated voltage:

TABLE 8-1, NORMAL LIGHTING LEVELS

Area	Measurement Location	Minimum Average Lighting Level[1]	Minimum Single Reading[1]
Within the vehicle	At elevation of 840 to 1675 mm (33 to 66 in) above the floor	215 lux (20 fc)	22 lux (2 fc)
Passenger aisles and articulation section	At the floor	110 lux (10 fc)	11 lux (1 fc)
Vehicle entrances and exits[2]	Within 500 mm (20 in) of the doors at the floor	110 lux (10 fc)	11 lux (1 fc)
Door thresholds and platform	On platform surface 915 mm (36 in) from vehicle side	55 lux (5 fc)	6 lux (0.6 fc)
Stairways (if applicable)	Surface of the steps	55 lux (5 fc)	6 lux (0.6 fc)
Cab (from ceiling light)	At 840 mm (33 in) above the floor	215 lux (20 fc)	22 lux (2 fc)
Cab (console-mounted light)	On the Cab Console	215 lux (20 fc)	22 lux (2 fc)

Notes to Table:

1. Average value shall comply with the specified minimum, and no single value shall fall below the specified minimum single reading value (i.e. no dark spots).
2. Requirement for average value applies to each entrance/exit, not to all entrances/exits on the vehicle averaged together.

8.4 Contrast Ratios

Select lighting fixtures such that maximum contrast ratios do not exceed the values specified below:

TABLE 8-2, CONTRAST RATIOS

Area	Maximum Contrast Ratio
Adjacent ceiling from lighting fixture	40:1
Walls to lighting fixtures (except windows)	10:1

8.5 Power Source and Control

Comply with the following:

1. Lighting power source: DC low-voltage power supply (LVPS), without intermediate power supplies or dropping resistors. See Section 9, Electrical Equipment, for requirements of the dc LVPS and emergency power.

2. Lighting Control:

   a. Dimming (where specified):

      - Lighting: Use PWM dimming and LED drivers specifically designed for use with PWM dimming.
      - Indicators: LEDs, such as on the Cab Console, may be powered from a separate PWM supply.

   b. Electronic controllers: Comply with the design requirements specified in Section 17, Controls, Networks, and MDS.

   c. See Section 5, Operator's Cab Controls, for additional control requirements.

8.6 General Fixture and Lamp Requirements

Comply with the following general requirements:

1. Maintainability: All lighting fixtures shall have easy access for lamp replacement, cleaning, and maintenance:

   a. Lamp access: Via gasketed enclosure covers secured by captive, stainless steel fasteners, except for permanently-sealed light fixtures.

   b. Enclosure covers: Retained by hinges, where possible. Hinges located on the vehicle exterior shall be stainless steel.

2. Lighting fixtures: Integral, shatterproof, frosted diffuser/lens. Clear lenses are not permitted except for indirect lighting applications.

3. Lamps:

   a. For illumination purposes:

      - Type: White LED assemblies
      - Voltage range: Provide full illumination within the range specified in Section 9, Electrical Equipment
      - Passenger area: Energy Star® Qualified, or equivalent documented performance, when installed in the proposed fixtures
      - Life expectancy: Minimum 50,000 hours, in the proposed fixtures

   b. For indicators:

      - Life expectancy: Minimum 100,000 hours

8.7 Interior Lighting

8.7.1 General

Comply with the following:

1. Performance: Provide lighting free from glare.
2. Diffusers: Frosted-type, such that individual LEDs are not discernible.
3. Lighting levels: Provide as specified in Table 8-1, Normal Lighting Levels.
4. Contrast ratios: Provide as specified in Table 8-2, Contrast Ratios.
5. Fixture assemblies:
    a. Shall be rattle-free, vandal-resistant, IK10 impact rated, and dustproof.
    b. Fixtures within 610 mm (2 ft) of a doorway shall be IP66 watertight except for interior ceiling lights.
6. Flammability, Smoke Emission, and Toxicity: Light fixture, lamp, and associated parts or equipment shall meet the guidelines specified in Section 16, Materials and Workmanship.

8.7.2 Passenger Area Lighting

8.7.2.1 General

Comply with the following:

1. Correlated Color Temperature (CCT): Mimic the color of warm white (3000K) or cool white (4000K) in accordance with ANSI C78.377.
2. Color Rendition: Adjust CCT as necessary to complement SEPTA's choice of interior colors.
3. Control: Automatic; see Section 5, Operator's Cab Control.

8.7.2.2 Main Linear Lighting

Provide linear lighting fixtures in the main passenger areas:

1. Type: Ceiling mounted, recessed, and integrated into the interior finish.
2. Continuous Illumination: When viewed from the end of the vehicle, there shall be no visible dark spots, such as where electronic controllers might be located.
3. Circuits shall be staggered such that the loss of a single lighting circuit prevents visible dark spots when viewed from the end of the vehicle.
4. Door area: Provide a minimum of one overhead standard-length light fixture at each door area to providing illumination in accordance with Table 8-1, Normal Lighting Levels. See Emergency Lighting, below, for requirements in case of power failure.

8.7.2.3 Doorway Floor Lights

Provide light fixtures at each doorway for threshold and platform illumination:

1. Location: Mount near floor on doorposts, windscreen, or other location that will produce the required minimum illumination (see Lighting Levels table, above).

2. Operation: The light shall be illuminated when the passenger door starts to open and extinguished when the door is closed and locked.

3. Alternate: If emergency passenger area lights furnish the required lighting level for door threshold and platform illumination, dedicated doorway floor lights may be omitted.

8.7.2.4 Stairway Floor Lights

Provide sufficient light fixtures at each stairway to furnish the required minimum illumination specified in Table 8-1, Normal Lighting Levels.

1. Control: Automatic; the lights shall be illuminated when the interior lights are illuminated.

8.7.3 Cab Lighting

8.7.3.1 Operator's Cab Ceiling Light

Provide a ceiling-mounted light fixture in each cab to illuminate the Cab Console:

1. Light Location: The light beam shall be placed to avoid glare on the windshield.

2. Control:

    a. On/Off: Via a switch on the Cab Console, as specified in Section 5, Operator’s Cab Controls.

    b. Dimming: Via a rotary switch located on the Cab Console as specified in Section 5 and dimming as specified in this Section.

8.7.3.2 Cab-Console-Mounted Light

Each Cab Console shall be illuminated to enable the Operator to see the console labels, pushbuttons, and switches under varying lighting conditions:

1. Light Location: Mount at the top edge of Cab Console, shielded from Operator's eyes.

2. Glare: When illuminated, light shall not cause glare on the windshield or the Cab Console.

3. Control:

    a. On/Off: Automatic; see Section 5, Operator’s Cab Controls.

    b. Dimming: Via a rotary switch located on the Cab Console, as specified in Section 5, and dimming as specified in this Section.

8.8 Exterior Lighting

8.8.1 General

Comply with the following:

1. Fixture assemblies:

    a. Secure, rattle-free, vandal-resistant, IK10 impact rated, IP66 dustproof and waterproof.

    b. Mount to vehicle with gaskets to prevent water ingress into the vehicle. Caulks, sealers, and similar materials are prohibited.

2. Bezels and trim:

    a. Stainless steel: If light fixtures are specified to have bezels and trim, or if proposed fixtures have bezels and trim.

    b. Fasteners: Captive stainless steel, and consistent with good mechanical mounting principles, per Section 16.

8.8.2 Headlights

Comply with the following requirements for headlights:

1. Type: LED with high beam and low beam; adjustable to permit proper aiming of beams.

2. Standards: Comply with the requirements of SAE J1383 and 49 CFR 571.108, Table I-a, Required Lamps and Reflective Devices.

3. Location: Provide on each side of each end of the vehicle.

4. Life: Minimum 50,000 hours.

5. Heat management:

    a. Comply with headlight manufacturer's clearance and airflow recommendations to maintain temperatures within LED manufacturer's recommended limit.

    b. Ensure that adjacent components have sufficient clearance and protection from high-temperature areas of the headlights to prevent heat damage.

6. Visibility: Capable of revealing a person or motor vehicle in clear weather at a distance of 107 m (350 ft).

7. Adjustment: Set so as not to interfere with the vision of drivers of motor vehicles.

8. Control: As defined in Section 5, including appropriate circuitry for low/high beam cycling function and headlights flashing.

8.8.3 Taillights and Stop Lights

Comply with the following requirements for taillights and stop lights:

1. Type: Permanently sealed plastic LED assemblies, colored as indicated.
2. Taillights:
    a. Quantity: Two at each end of each vehicle
    b. Color: Red
    c. Standards: Comply with requirements of SAE J2040 and 49 CFR 571.108, Table I-a, Required Lamps and Reflective Devices.
    d. Visibility: Plainly visible from a distance of minimum 150 m (500 ft), when illuminated
    e. Running taillights with a bar light
    f. Brake lights to flash with brake application.
3. Stop lights:
    a. Quantity: Two at each end of each vehicle
    b. Color: Red
    c. Intensity: Approximately 150% of the intensity of the taillights
    d. Standards: Comply with requirements of SAE J2261 and 49 CFR 571.108, Table I-a, Required Lamps and Reflective Devices.
4. Combination: Alternatively, the taillights and stop lights may be combined.
5. Control: Automatic; see Section 5.

8.8.4 Marker Lights

Comply with the following requirements for marker lights:

1. Type: Permanently sealed plastic LED assemblies, colored as indicated.
2. Standards: Comply with the requirements of SAE J1889, SAE J2042, SAE J2139, and 49 CFR 571.108, Table I-a, Required Lamps and Reflective Devices, as indicated for vehicles 30 feet or longer and 2032 mm or more in overall width.
3. Visibility: Plainly visible from a distance of minimum 150 m (492 ft), when illuminated.
4. Quantity and Location:
    a. On each side of the vehicle:
        - One amber light located as close to each end as possible for a total of two (front side marker lights)

- One amber light located at or near the midpoint (intermediate side marker light)
- One red light located as close to each end as possible for a total of two (rear side marker lights)

b. On each end of the vehicle:

- Two amber marker lights located symmetrically about the vertical centerline to indicate the overall width, located as near the top as practicable (front clearance lamps)
- Two red marker lights located symmetrically about the vertical centerline to indicate the overall width, located as near the top as practicable (rear clearance lamps)

5. Control: Automatic; see Section 5.

8.8.5 Turn Signals

Comply with the following requirements for turn signals:

1. Type: Left and right flashing arrows, permanently sealed plastic LED assemblies, colored as indicated.

2. Location: Front, sides, and rear of vehicle. On vehicle ends, turn signals may be integrated with headlights or other lights in accordance with 49 CFR 571.108 and as **approved**.

3. Standards:

   a. Comply with SAE J1889, SAE J2139, and 49 CFR 571.108, Table I-a, Required Lamps and Reflective Devices.

   b. Front and rear turn signals: Comply with the requirements of SAE J2261.

   c. Side turn signals: Comply with the requirements of SAE J2039.

4. Visibility: Plainly visible from a distance of minimum 150 m (492 ft) when illuminated.

5. Control: See Section 5, Operator's Cab Controls, for normal control and use of turn signals as hazard lights.

8.9 Emergency Lighting

Comply with the following requirements for emergency lighting:

1. Standard: APTA RT-VIM-S-020-10

2. Power Source: DC LVPS, and in the event of loss of normal power, from emergency power. See Section 9, Electrical Equipment, for additional information on the dc LVPS and emergency power.

3. Duration: See Section 9, Electrical Equipment.

4. The following are considered emergency lighting:

   a. Doorway overhead lights

b. Doorway floor lights

c. Stairway lights

d. Overhead lights, as needed to meet required lighting levels.

e. Active cab, overhead lights

f. Active cab, Cab Console lights

g. Exterior lights

8.10 Wiring Requirements

Comply with the following requirements for wiring of lighting:

1. Lamp circuits shall be electrically isolated from the fixture and the vehicle structure.

2. Metallic fixtures and exposed metallic surfaces shall be grounded to the vehicle structure as specified in Section 9.

8.11 Contract Deliverables Requirements List (CDRL)

8-1 Lighting System Design Package
8-2 Emergency Lighting System Design Package
8-3 Flicker Measurement and Design Package

8.12 CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

5. Software functional descriptions: Include top level control parameters and values

8-1 Lighting System Design Package:

1. The design package may be submitted as two packages, interior and exterior lights.

2. Include the following:

    a. Verification of lighting performance by computer analysis, including emergency lighting.
    b. Drawing of each lighting fixture.
    c. Drawing of the vehicle showing light fixture locations and identities.

d. Listing of lamps by function, type, part numbers, and source of U.S. supply.
e. Energy Star® Certification for passenger area lighting, or comparable documentation.
f. Warranty information for all equipment, including LED lamps.
g. Nominal electrical load of the lighting system, measured in kW.

8-2 Emergency Lighting System Design Package:

1. Emergency lighting load calculations.

8-3 Flicker Measurement and Design Package

8.13 Referenced Standards

The following standards are referenced in this Section:

49 CFR 38 Subpart D	Light Rail Vehicles and Systems
49 CFR 571.108	Standard No. 108; Lamps, reflective devices, and associated equipment
ANSI C78.377	American National Standard for Electric Lamps--Specifications for the Chromaticity of Solid-State Lighting Products
APTA PR-E-RP-012-99	Recommended Practice for Normal Lighting System Design for Passenger Cars
APTA RT-VIM-S-020-10	Emergency Lighting System Design for Rail Transit Vehicles
IEEE 1789-2015	IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers
SAE J1383	Performance Requirements for Motor Vehicle Headlamps
SAE J1889	L.E.D. Signal and Marking Lighting Devices
SAE J2039	Side Turn Signal Lamps for Long Vehicles
SAE J2040	Tail Lamps (Rear Position Lamps) for Use on Vehicles 2032 mm or More in Overall Width
SAE J2042	Clearance, Sidemarker, and Identification Lamps for On-Road Vehicles 2032 mm or More in Overall Width
SAE J2139	Tests for Signal and Marking Devices Used on Vehicles 2032 mm or More in Overall Width
SAE J2261	Stop Lamps and Front- and Rear-Turn Signal Lamps for Use on Motor Vehicles 2032 mm or More in Overall Width

END OF SECTION

Table of Contents

Table of Tables

9.1 General

9.1.1 Scope

This Section specifies general electrical requirements; electrical systems not addressed in their own sections; and electrical components used throughout the vehicle.

Electrical materials, including but not limited to conduit, wireway, junction boxes, wire, and cable, are specified in Section 16, Materials and Workmanship.

The equipment specified in this Section shall be tested in accordance with the requirements specified in Section 15, Testing.

9.1.2 Definitions

The definitions provided in this Section are meant to complement those included in Section 1, General Topics and Definitions. The following definitions apply to terms used in this Section:

1. High-Voltage DC: DC power from the OCS, Shop power, or regenerative braking.
2. Low-Voltage DC: DC power from the low-voltage power supply (LVPS) or low-voltage battery.
3. Auxiliary: Circuits and systems for loads other than propulsion.
4. Auxiliary Power System: For supply of auxiliary loads not powered by high-voltage dc. Includes auxiliary ac inverter and dc LVPS.

9.2 General Electrical Requirements

9.2.1 Equipment Enclosures

Electric or electronic equipment shall be enclosed in equipment enclosures, unless specified otherwise. Equipment enclosures are specified in Section 14, Interior and Exterior Appointments.

9.2.2 Electrical/Electronic Design Standards

Electrical and electronic equipment shall comply with the requirements of IEC 60571 or IEEE Std 16.

9.2.3 Equipment Voltage Range

Comply with the following:

1. Electrical equipment shall operate as specified and without damage over the full operating range of its source voltage, and the worst-case voltage drop in the distribution system.
2. All equipment shall be protected against damage from voltages outside the specified range, or their design range, whichever is greater.
3. Equipment operating from the auxiliary ac inverter shall operate as specified and without damage at any voltage within the limits specified in the Auxiliary AC Inverter section, below.

4. Equipment operating from the dc LVPS shall be rated for continuous operation at the actual LVPS terminal voltage, in compliance with the DC Low-Voltage Power Supply section, below.

5. Equipment operating from the battery without the battery charger shall operate as specified and without damage at the battery voltage resulting from discharge to a low voltage per battery cell.

9.2.4 Circuit Protection

Comply with the following:

1. Arrange circuit protection in a logical branching organization to facilitate fault isolation and minimize operational impacts on other systems:

    a. Coordinate local circuit protection with main source protection such that faults or overloads downstream of the local protection shall trip the local protection only, and not trip the main source protection.

    b. Local protection trip settings shall be lower than the main source power or current limit settings.

2. Size circuit breakers and fuses, where **approved**, to protect both the equipment and the minimum wire size used for power distribution within the protected circuit.

3. Individually protect each circuit as follows:

    a. Propulsion high-voltage dc circuits: High speed circuit breaker (HSCB).

    b. Auxiliary high-voltage dc circuits: High speed dc fuses rated minimum 1000 Vdc. Contractor may propose high speed circuit breaker in place of fuses. HSCB shall be equipped with reset limits.

    c. AC circuits: Circuit breakers.

    d. Low-voltage dc circuits: Circuit breakers.

4. Location of circuit protection devices:

    a. Mount ac and low-voltage dc circuit breakers in panelboards located in electrical lockers in each Operator's cab (see Section 14, Interior and Exterior Appointments, for electrical locker and key requirements). Group low-voltage dc control breakers logically.

    b. AC loads that are in the cab shall have their respective breakers in the cab.

    c. Locate other ac distribution breakers within the vehicle such that they may be readily inspected by the Operator but are not accessible to passengers.

    d. Locations other than those specified require **approval**.

5. Temperature compensation:

    a. For thermal magnetic circuit breakers, the thermal trip settings shall include compensation for temperatures in the installed environment.

   b. If thermal magnetic circuit breakers cannot accommodate the temperature in the installed environment, provide hydraulic magnetic circuit breakers.

6. Display the OFF state of all circuit breakers for those systems that do not report failure status to the TOD upon loss of power, such as track brakes.

9.2.5 Arc-Flash Hazard Analysis

Perform an Arc-Flash Hazard Analysis with the aid of computer software intended for this purpose.

1. AC System: Perform analysis in accordance with IEEE Std 1584 and include results as required by NFPA 70E.

2. DC System: Perform analysis in accordance with industry suggested techniques and include results as required by NFPA 70E.

3. Perform the analysis under worst-case fault conditions.

9.2.6 Grounding and Return Circuits

Size all grounding and high-voltage return conductors, ground brushes, and related components to limit voltage rise to less than 50 V under worst case fault currents.

9.2.6.1 Shunting Resistance

See Section 11, Truck Assemblies, for wheel shunting resistance requirements. See Section 15, Testing, for required resistance tests.

9.2.6.2 Safety Grounding

Comply with the following:

1. Safety ground all conductive equipment on the vehicle to the vehicle structure, including metallic raceways, resiliently mounted equipment, enclosures, the truck frame, and truck mounted equipment.

2. Safety ground the vehicle structure to the axles using dedicated safety ground brushes.

3. Safety ground axles to wheel tread with shunts as specified in Section 11, Truck Assemblies.

9.2.6.3 High-Voltage Return Circuits

Comply with the following:

1. Connect all high-voltage return circuits to an isolated return current terminal for each propulsion and auxiliary ac inverter unit per vehicle section.

2. Interconnect these isolated return current terminals throughout the vehicle.

3. Connect these isolated terminals to all brushes on the corresponding truck by ground wires of identical impedance.

4. Install an isolated ground plate within the truck if needed to facilitate impedance balance for each ground brush.

5. Provide high-voltage dc current return to the running rails as follows:

   a. Connect the high-voltage dc return circuits to the axle using ground brushes and to the rail using the wheels with appropriate visible shunts around the wheel resilient elements. See Section 11, Truck Assemblies, for additional requirements related to wheel assembly conductive paths.

   b. Prevent any current return through the journal bearings, gear units, or motor bearings.

9.2.6.4 Low-Voltage Return Circuits

Provide return wiring for each system or circuit fed from a circuit breaker or fuse.

1. Each circuit return wire shall be connected, via its own separate terminal, to a return bus located in the same electrical locker that contains the circuit breaker that supplies the circuit.

2. Ground the return circuits as follows:

   a. Connect the low-voltage dc return circuits to the vehicle structure through an RC filter at a single point only.

   b. Ground the ac neutral at a single point.

3. The vehicle structure shall not be used as a normal circuit-return path for any electrical equipment.

9.2.6.5 Ground Brushes

Provide ground brushes for each wheel or for each through-axle in a conventional (non-stub axle) truck:

1. Rating: 2.0 times the circuit rms current, and 1.5 times the circuit peak current.

2. Life: Minimum 500,000 km (310,686 mi).

9.2.6.6 Grounding Conductors

Grounding wires to fixed equipment may be standard vehicle wiring (see Section 16, Materials and Workmanship).

Provide tinned, braided copper ground cables fitted with flared terminal barrels designed for strain relief for the following applications:

1. Grounding connections to resiliently-mounted equipment.

2. Grounding connections between the vehicle body and truck frame.

3. Grounding connections in other locations with relative movement.

9.2.6.7 Grounding Connections

Grounding connections to vehicle body, truck frame, and other vehicle structures:

1. Ground pads: Provide welded stainless-steel pads, or tinned or silver electro-plated copper pads silver soldered or brazed to both the vehicle body and the grounded item, through-drilled.

2. Connection: Fasten the ground wire to the ground pad using a bolt, flat washer, and locknut. The flat washer shall bear on the ground wire terminal.

3. Aluminum structures:

   a. Weld an aluminum ground pad onto the structure. Thick aluminum structures may not require a separate ground pad, if **approved**.

   b. Through-bolt the ground cable to the structure with zinc-plated steel fasteners and washers.

   c. Treat the connection with an anti-corrosion paste.

4. DC resistance: Maximum 0.0025 ohms.

5. AC impedance: Maximum 0.025 ohms at 150 kHz for an applied ac voltage.

9.2.7 Ground Fault Detection and Protection

The vehicle shall have ground-fault protection at the inputs of high-voltage dc equipment, and generic ground-fault protection for ac circuits, low-voltage circuits, and ac convenience outlets.

9.3 Equipment Temperature Management

Comply with the following:

1. Cooling systems shall be air-cooled.

2. Traction motors shall be either forced-air cooled or self-ventilated.

3. Forced-air cooled systems: Use ambient air only where exposed voltage is 50 V or less.

4. Motors for fans: Three-phase ac or dc brushless, except as specified in the Failure Management section, below.

5. Equipment temperatures:

   a. Continuously monitor via sensors or, where appropriate, by calculation.

   b. Manage system power levels as necessary to protect equipment from over-temperature damage.

   c. Record abnormal temperatures, temperature trends, and resulting equipment power limitations and present to the MDS.

9.4 Primary Power System (OCS)

9.4.1 General

Equipment operated from the OCS shall comply with the Primary Line Voltage requirements specified in Section 2, Design and Performance Criteria.

9.4.2 Pantograph

9.4.2.1 General

Vehicle power shall be collected from the OCS by a roof-mounted pantograph:

1. Type: Service-proven, single-arm design, with a spring-suspended contact assembly capable of stable bi-directional operation at all specified vehicle speeds and external system characteristics.

2. Dimensions and operating height range: Comply with Section 2.

3. Bearing Shunts: Provide tinned, braided copper conductors around all pantograph moveable joints.

9.4.2.2 Contact Assembly

Comply with the following:

1. Type: Double carbon with replaceable carbon inserts of one-piece design.

2. Dimensions: See Section 2, Design and Performance Criteria.

3. Maintainability: Contact assembly and carbon inserts shall be individually replaceable with common hand tools.

4. Provide ice scraping collection heads that directly replace the carbon collectors, as spares, in sufficient quantity to replace 25% of the fleet.

9.4.2.3 Contact Force

Contact force on the contact wire shall be adjustable and shall be selected for optimum tracking and minimum wear:

1. Range: 64.5 N to 86.7 N (14.5 lbf to 19.5 lbf).

2. Linearity: Contact force shall vary by maximum 22 N (5 lbf) over the combined full ranges of operating height, vehicle speed, and direction.

9.4.2.4 Dynamic Stability

Pantograph dynamic stability shall be sufficient to maintain contact and stable wire tracking at the specified speeds on all tracks at all contact wire heights and transition grades.

9.4.2.5 Pantograph Raising and Lowering

Comply with the following:

1. Manual raising and lowering:
    a. Make provision to manually lower and raise the pantograph in the event of loss of power or control.
    b. The manual mechanism shall be operated from within the vehicle, using a hand crank or similar tool.
    c. Provide a switch in the manual operator socket that disconnects motor power while the manual operator is inserted.
    d. Provide one tool for each vehicle, plus five spares.
    e. Provide tool storage in the cab. See Section 5, Operator's Cab Controls.
2. Pantograph raising:
    a. The pantograph shall be spring raised when the restraining mechanisms are released.
    b. The raising speed shall be damped or otherwise controlled to prevent carbon strip damage upon striking the OCS. This speed control and damping shall be active only during the raising process and shall be inactive during normal wire tracking.
3. Raising and lowering circuit:
    a. Shall be possible to lower the pantograph from either cab but raise only from the active cab, by a Pantograph Up/Down Switch on the Cab Console. It shall be possible to lower the pantograph at any speed but raising shall be possible only when vehicle is stationary.
    b. Lowering of the pantograph by any means shall not affect any requested brake rate and shall result in a coast mode if the vehicle is in a coast or power mode.
    c. Lowering command of the pantograph shall open the HSCB and turn off the auxiliary ac inverter.
    d. Electric raising and lowering mechanisms shall operate throughout the voltage range specified for low-voltage equipment.
    e. Provide a cushioned stop when lowering the pantograph to prevent damage due to impact.
4. Pantograph restraining mechanism:
    a. Provide a mechanism to automatically restrain the pantograph in the fully lowered position.
    b. The mechanism shall function at all times regardless of failures in power, control, or other system elements.
    c. A restrained pantograph shall be electrically isolated from the downstream vehicle electrical circuitry. This shall be performed automatically by detecting the restrained pantograph and opening the traction and auxiliary high-speed circuit breakers.

d. A restrained pantograph shall be automatically grounded to the vehicle ground network.

e. The mechanism shall provide an output signal to the CBTC system verifying when the pantograph is lowered and positively restrained. This signal is provided for the coordination of dynamic brake operation in coordination with the requirements specified in Section 21, Communications Based Train Control.

f. The mechanism shall be released automatically when the pantograph is commanded to be raised while the vehicle is stationary. The pantograph raising operation shall be possible only if all existing faults are cleared that might result in damage to the pantograph or vehicle circuitry.

5. Pantograph auto-drop feature:

   a. The pantograph shall incorporate an auto-drop/breakaway mechanism that automatically causes the pantograph to lower and restrain in fully lowered position whenever the pantograph encounters an overhead obstruction, experiences a broken carbon strip, or OCS contact wire slides off from the carbon strip.

   b. The activation of auto-drop feature shall result in emergency break application.

   c. Once auto-drop feature is activated, an event shall be logged in the MDS system and the Operator shall be notified with visible and audible alarm indication in the cab.

   d. It shall be possible to disable the auto drop feature for maintenance tasks with automatic return to necessary functionality when maintenance tasks are complete.

9.4.3 High Speed Circuit Breaker

Provide a roof-mounted HSCB to protect the propulsion high-voltage dc power circuits:

1. Standards: Comply with IEC 60077-1, IEC 60077-3, and IEC 61373.

2. Power supply: DC LVPS.

3. Performance:

   a. Tip opening in maximum 10 ms

   b. Complete arc extinguishment and fault interruption in less than 50 ms

   c. Shall be designed for a minimum of 200,000 mechanical operations

4. Trip values and ratings: Coordinate with the traction electrification system supplier such that the HSCB will clear all vehicle system fault currents without nuisance trips of the wayside breakers.

5. Trip and reset capability:

   a. Remote trip by the propulsion logic, in case of propulsion fault on any propulsion inverter supplied by the HSCB, and reset from the cab, by using the HSCB (Propulsion) Reset switch specified in Section 5, Operator's Cab Controls.

b. Limit the number of electrical resets to three within any 15-minute period, after which resetting shall be possible via the portable test unit (PTU) and MDS maintenance screen. The number of trips and time period for this setting shall be adjustable.

6. Provide annunciation of a tripped or open HSCB to the Operator as specified in Section 5, Operator's Cab Controls.

9.4.4 Battery Charging

The LVPS shall charge low-voltage batteries whenever the high-voltage dc power is available either from OCS or the shop power, regardless of mode of operation:

1. Battery charging shall not depend on the state of the HSCB.
2. See Backup Battery section, below, and Section 5, Operator's Cab Controls, for additional requirements.

9.4.5 Dead Battery Operation

All vehicle systems shall start automatically, and function as specified, whenever there is high-voltage dc power available from OCS or shop power, regardless of the charge state of the low-voltage battery.

9.4.6 Surge Arrester

Provide an MOV-type surge arrester suited for rail application, on or adjacent to the pantograph base:

1. Type: Rated by the manufacturer for outdoor dc operation.
2. Standards: Designed, constructed, and tested in accordance with EN 50526-1.
3. Rating and Class: Selected to prevent voltage transients, lightning strikes, and surges from damaging or degrading vehicle-borne equipment, including the arrester itself.

9.5 Maintenance Shop Power

9.5.1 General

Power to the vehicle while in the Shop will be 600 Vdc supplied by OCS or a plug-in cable from the Shop Vehicle Power Unit (SVPU), provided by others.

9.5.2 Coordination

Coordinate with the Engineer during design and construction of the Shop to ensure compatibility of the vehicle with the Shop:

1. Furnish a summary of vehicle loads that will be powered from the Shop to ensure compatibility of Shop circuit sizes with vehicle loads. Reduce loads if necessary for compatibility with the Shop.
2. Ensure that Owner-furnished SVPUs are compatible with vehicle plugs and interlocking.

3. Furnish a dimensioned sketch showing the location of the receptacle on the vehicle to allow designers to locate SVPUs correctly in the Shop.

9.5.3 Shop Switch

Provide a dedicated transfer switch on the vehicle as follows:

1. Location: Roof or an alternate location if **approved**.

2. Type: Fully enclosed, three-position rotary-type.

3. Positions:

    a. Off, Normal mode, and Shop mode.

    b. Clearly marked on the outside.

4. Operating handle:

    a. Easily operable with one hand.

    b. Grounded to the enclosure.

5. The switch shall operate as follows:

    a. Off mode:

        - Disconnect pantograph from all vehicle circuits
        - Disconnect shop voltage from all vehicle circuits

    b. Normal mode:

        - Disconnect shop voltage from all vehicle circuits
        - Connect pantograph to ac inverter, traction inverters, and other line-voltage-operated equipment

    c. Shop mode:

        - Disconnect pantograph from all vehicle circuits
        - Disconnect the propulsion system from auxiliary ac inverter and LVPS input circuit, in case they share a common input circuit.
        - Connect shop voltage only to auxiliary ac inverter, LVPS input circuit, if powered directly from line voltage shop power
        - Provide an interlock in the shop switch to prevent the pantograph from moving in this mode.
        - Vehicle movement shall not be possible in this mode and propulsion shall be inhibited.

    d. Under no circumstances shall the propulsion system, pantograph, or pantograph frame be energized by shop mode.

    e. In normal mode and shop mode, it shall be possible to start up the LVPS and charge the vehicle battery to recover from partial or completely discharged state, as specified in the Dead Battery Operation section.

6. Shop Switch Enclosure:

    a. Box: Painted steel, stainless steel, or aluminum; grounded to the vehicle structure.

    b. Cover: Latching hinged type or threaded, watertight when subjected to a water test equal in severity to that for the vehicle body; grounded to the enclosure with ground strap.

    c. Interior: Fully insulated with no grounded components inside.

9.5.4 Receptacle and Plug

Provide receptacle, mating plug, and associated equipment rated for the maximum continuous and peak auxiliary currents to allow connection to the SVPU:

1. Receptacle:

    a. Location: On the roof, on the shop switch enclosure, or in an alternate location if **approved**.

    b. Grounding: If the receptacle body is metallic, it shall be grounded to the vehicle structure.

    c. Model: Verify that the receptacle is acceptable for the proposed load.

2. Plug:

    a. Furnish 10 mating plugs to the Engineer for installation on the shop cable by others and 10 mating plugs to the Engineer for spares.

    b. Furnish plugs no later than 120 days before delivery of the first vehicle.

3. Interlocking:

    a. The receptacle and plug shall include interlock contacts to ensure that the SVPU is energized only when the SVPU cable is plugged into the receptacle. Arrange interlock contacts on the receptacle/plug to break before the main receptacle/plug power contacts separate when removing the plug.

    b. The receptacle and plug shall include vehicle-side interlock contacts to ensure that propulsion is prevented at any time the plug is connected to the vehicle receptacle. An alternate approach ensuring the plug is disconnected from the enclosure receptacle may be proposed.

    c. Provide a means to lock out the active position of the shop switch, so that it is not possible to move the switch from one position to another without removing the lock.

9.5.5 Auxiliary Loads Under Shop Mode

Comply with the following:

1. Under Shop mode, the following loads shall be powered, unless otherwise **approved**:

    a. All ac loads, including maximum HVAC loads.

    b. All low-voltage dc loads and battery charging.

2. Verify that vehicle circuits and loads stay within the **approved** limits, as specified in the Coordination section, above.

9.6 Auxiliary Power System

9.6.1 General

The auxiliary power system includes an auxiliary ac inverter for ac auxiliary loads and a dc LVPS for low-voltage dc auxiliary loads. The auxiliary ac inverter and LVPS may be packaged together and may share components or may be separate.

9.6.2 Auxiliary AC Inverter

9.6.2.1 Auxiliary AC Inverter Requirements

Provide a source of three-phase ac and single-phase ac power for ac auxiliary loads identified in the Specifications.

1. Voltage/Frequency:

    a. Single-phase: AC source voltage shall be 120 Vac, 60 Hz.

    b. Three-phase:

        - AC source voltage shall be 230 V, 60 Hz or a voltage level otherwise **approved**
        - Output voltage regulation: +/- 5%
        - Output frequency tolerance: +/- 2%
        - Distortion under nominal load: Less than 10%
        - Maximum dv/dt of the output voltage: Less than 10 V/µsec
        - Phase-to-phase voltage imbalance under worst-case phase load imbalance: Maximum 5%
        - Power factor: Higher than 0.95

2. Size: Auxiliary ac inverters shall be sized for the worst-case continuous operation of all loads, including convenience outlets specified in Section 14, Interior and Exterior Appointments, and the maximum peak individual load with all other steady-state loads applied, plus 15% additional capacity, as per IEEE 1476, Annex A.

3. Configuration:

    a. Provide one or two independent auxiliary ac inverters, powered from the high-voltage dc power system and supplying power to the ac auxiliary loads.

    b. Each auxiliary ac inverter shall supply the loads for either the complete vehicle or in its respective vehicle half (see Failure Management section, below).

    a. If forced ventilation is provided, it shall require minimal maintenance interventions. If filters are used, the replacement interval shall be annual or higher.

4. Operation:

    a. The auxiliary ac inverters shall start automatically and operate at full performance when the steady-state input voltage is within the supply normal voltage range specified in Section 2, Design and Performance Criteria.

    b. The auxiliary ac inverters may shut down when the steady-state input voltage is less than or greater than the range specified in Section 2.

5. Isolation: The output of the auxiliary ac inverters shall be galvanically isolated from the high-voltage dc power system.

9.6.2.2 Auxiliary AC Inverter Controls

The controls for the auxiliary ac inverters shall prevent damage to connected equipment and the auxiliary ac inverter itself, resulting from the following:

1. High and low frequency
2. Over- and under-voltage
3. Out-of-tolerance voltage-to-frequency ratio
4. Frequent repetitive starts (manufacturer defined limits)
5. Rapid variations and transients in line voltage or loads
6. High-voltage dc power interruptions
7. Excessive harmonic distortion
8. Phase loss
9. Overload

The control logic shall permit the equipment to automatically restart after shutdowns caused by self-correcting failure conditions. Major faults shall latch the equipment off until reset by maintenance personnel.

9.6.2.3 Auxiliary AC Inverter Fault Monitoring

Provide a fault monitoring system to automatically detect auxiliary ac inverter status and transmit the information to the MDS in the Operator's cab via the vehicle network (see Section 17, Controls, Networks, and MDS).

9.6.2.4 Auxiliary AC Inverter Failure Management

Loss of a single auxiliary ac inverter shall not result in loss of propulsion, brakes, or other functions critical for vehicle operation:

1. Vehicle equipped with two auxiliary ac inverters:

    a. Include provisions to transfer ac power for essential loads to the second or a back-up auxiliary ac inverter in the event of an inoperable auxiliary ac inverter.

    b. As a minimum, a vehicle with a failed auxiliary ac inverter shall be able to operate over the whole alignment without speed restriction on its own power from the remaining auxiliary ac inverter with all safety and vehicle-operation-related functions operational, including maintaining power to the following:

    - Circuits for propulsion cooling, and other ac loads required by the propulsion system
    - Critical friction brake loads, where permitted to be powered by the ac source.

    c. The ratings of each auxiliary ac inverter shall include these redundant transfer loads in addition to its normal loads.

    d. The transfer mechanism may be via three-phase transfer breakers, or other **approved** methods.

2. Vehicle equipped with one auxiliary ac inverter:

    a. The critical loads, including propulsion cooling, shall be operated from the vehicle's low-voltage dc power system.

    b. A vehicle with a failed auxiliary ac inverter shall be able to operate over the whole alignment without performance restriction.

    c. Motors used in critical components shall be brushless dc motors.

9.6.3 DC Low-Voltage Power Supply

Provide a nominal 24 Vdc LVPS or a voltage level otherwise **approved** for specified vehicle loads:

1. Comply with IEC 60571 for the selected nominal voltage system, except as may be specified elsewhere in the Contract Documents.

2. Size:

    a. Each LVPS or LVPS output channel shall have sufficient capacity to maintain terminal voltage at the regulated value while simultaneously charging a dead battery and providing adequate power to all vehicle low-voltage dc loads, for all body sections, with the assumption that the other LVPS or output channel is not functioning.

    b. If necessary, the LVPS may limit its peak current during track brake applications, allowing the battery to supplement the loads.

    c. Each LVPS shall have 20% reserve capacity for optional and future loads.

3. Configuration:

   a. Provide one or two independently-regulated LVPSs for each vehicle, each with separate, independently-controlled outputs for battery charging.

   b. Battery charging shall be controlled independently of the other dc load outputs. See the Battery Charger section, below, and Section 5, Operator's Cab Controls, for additional battery charging requirements.

   c. Designs that include the LVPS as part of the auxiliary ac inverter are acceptable. If combined, operation or failure of the LVPS shall not affect operation of the auxiliary ac inverter.

   d. If forced ventilation is provided, it shall need minimal maintenance interventions. If filters are used, the replacement interval shall be annual or higher.

4. Operation:

   a. The LVPS and battery charging shall automatically start when high-voltage dc power is applied. Battery power shall not be required as a prerequisite to starting, or for closing circuit breakers or contactors needed to permit LVPS operation.

   b. Transfer of loads to one LVPS with the loss of the other LVPS shall be automatic, and not require any action by the Operator. The transfer of loads shall include battery charging. When the failed LVPS resumes operation, the load transfer control shall detect this and automatically restore operation and load distribution between the two LVPS units.

5. Isolation: The LVPS output shall have complete galvanic isolation from the high-voltage dc power system.

9.7 Backup Battery

9.7.1 Battery Charger

Float-charge the low-voltage battery via the dedicated battery charging circuit that is part of the LVPS:

1. Charging algorithm shall be optimized for battery type.

2. The charger shall include a current-limiting feature that ensures the battery manufacturer's recommended charging current level is not exceeded.

3. The battery charging voltage and current shall be optimized for the battery selected by the Contractor, per the battery manufacturer's recommendations. The charging voltage and current shall be adjustable by PTU via software to allow alternative battery vendors. The adjustment may be restricted such that only authorized personnel can make adjustments.

4. Adjust charging voltages and currents automatically for battery temperature via a temperature sensor in the battery compartment.

5. Battery charging shall be provided and managed by one LVPS. If more than one LVPS is provided, include provisions to transfer battery charging between LVPSs in the event of LVPS/battery charging failure. The transfer circuit shall be automatic, or via a dedicated manual circuit.

9.7.2 Low-Voltage Battery

Provide a low-voltage battery to power emergency loads in the event of failure of the low-voltage power supplies:

1. Type: Appropriate battery chemistry for required energy density, load cycle, maintenance requirements, and safety.
2. Quality: Service-proven railway or transit quality.
3. Capacity: Sufficient to power emergency loads for the durations specified below.
4. Charging: From the LVPS battery charging output.
5. Charging voltage: Set as recommend by the battery manufacturer.
6. Standards: Battery design shall comply with either APTA PR-E-RP-007-98 or IEC 62620, depending on the selected battery type and chemistry. Battery connectors shall comply with APTA PR-E-RP-009-98.
7. Fire Safety: Battery and associated circuitry shall comply with NFPA 130.
8. Performance requirements at minimum outdoor temperature specified in Section 2, Design and Performance Criteria:
    a. Charge cycle rating 100% depth-of-discharge: 800
    b. Charge cycle rating 10% depth-of-discharge: 3000
    c. Maximum charge current (to 80% state-of-charge): 2C
    d. Maximum discharge current: 5C
    e. Minimum specific energy: 70 Wh/kg
    f. Minimum energy density: 200 Wh/L
    g. Minimum operational life: 15 years

9.7.2.1 Battery Enclosure

Provide a ventilated battery enclosure on the roof or under the vehicle and outside the passenger compartment, separated by a non-combustible barrier:

1. General:
    a. Size: Large enough to accommodate batteries from at least two independent suppliers.
    b. Integral Tray: Provide for capture of spilled electrolyte, only if a liquid-filled battery is provided.
    c. Material: Stainless steel

   d. Paint: If battery enclosure components are painted, they shall be impervious to electrolyte, only if a liquid-filled battery is provided.

2. Roof:

   a. Battery Removal: Design enclosure and battery installation such that it is possible to remove the complete set of battery cells from the enclosure all at one time using an overhead crane.

   b. Enclosure Covers:

      - Hinged, large enough to permit battery removal and inspection.
      - With features that prevent cover or hinge damage from over-rotation.

   c. Enclosure Structural Strength: Sufficient to withstand a 275-lb man walking on the covers without permanent deformation or contact with underlying circuits.

3. Under Vehicle: Provide roll-out tray to hold the batteries:

   a. Material: Stainless steel.

   b. Support: Ball-bearings.

   c. Extension Depth: Sufficient to permit battery to be fully extended such that all cells may be inspected and filled, only if a liquid-filled battery is provided.

4. The battery box shall be ventilated to meet the requirements of IEC 62485-2, as appropriate for the selected battery type.

9.7.2.2 Battery Circuit Breaker

Provide a circuit breaker for battery and battery-circuit protection:

1. Type: Two-pole dc breaker. Parallel circuit breakers are not permitted.

2. Rating: Sufficient to withstand the short circuit capacity of the battery.

3. Connection: To the B+ and B- leads from the battery terminals.

4. Low-voltage battery disconnect: Include provision to trip the breaker from the side of the vehicle, by persons standing on the ground.

9.7.2.3 Battery Heat Detection and Emergency Cutoff

Provide a heat detection system:

1. It shall trip the battery circuit breaker upon detection of excessive heat.

2. The temperature setting shall be as recommended by the battery manufacturer.

3. Record detected faults in local fault logs, and report to the MDS.

Provide an accessible emergency battery-cutoff switch if the battery circuit breaker is not accessible from the side of the vehicle or at a convenient interior location.

9.7.3 Battery Load Control

Provide automatic controls to prevent discharge of the low-voltage battery by parasitic loads when the MC key is switched to Off and the battery is not being charged.

Allow operation of passenger area lights until the Delayed-Off timer expires, if the vehicle loses battery charging after the Hotel Load timer is triggered (see Section 5, Operator’s Cab Controls).

9.7.4 Emergency Power

The low-voltage battery shall power emergency loads upon the loss of LVPS units or outputs:

1. Capacity: Sufficient to supply all the loads at the duty cycles shown in Table 9-1, below, as follows:
    a. First 30 minutes: All loads (Load Group1 + Load Group2 + Load Group3)
    b. Next 15 minutes: Only Load Group1 and Load Group2
    c. Next 45 minutes: Only Load Group1; no lower limit for battery voltage, except that the battery shall not be damaged.
2. Voltage: All indicated loads and systems shall have sufficient input voltage to operate for the specified duration.
3. Control:
    a. Provide the battery bus with a contactor for top-level control of bus power.
    b. Emergency loads shall be connected directly to the battery bus upon loss of normal power.
    c. Control of emergency power shall be via relay/contactor logic only without the use of software or electronics.

TABLE 9-1, EMERGENCY LOAD DUTY CYCLE			
Load Group	**Emergency Load**	**Operation**	**Duration (minutes)**
Load Group1	Emergency Lighting	Continuous	90
	Communications Critical (Public Address system and Intercom)	Continuous	90
	CBTC	Continuous	90
	Event Recorder	Continuous	90
	Interior and Exterior Camera and NVR	Continuous	90
	Ventilation fans (dc powered)	Continuous	90
Load Group2	Door Control	Cycle doors open for 20 seconds every 5 minutes	45
	Propulsion Control	Continuous	45
	Braking power and control, including pumps if dc operated	Continuous	45
	Cab Console indicators and interlocks	Continuous	45
	Horn and bell	On for 10 seconds every 2 minutes	45
	Track brakes	On for 10 seconds at end of each 20-minute period	45
	Pantograph Control	Raise and lower twice	45
	Headlights, taillights, and stop lights	Continuous	45
	Windshield wiper	Continuous	45
Load Group3	Communications Non-Critical (Advertising and Public Wi-Fi)	Continuous	30
	Collision Avoidance System	Continuous	30
	Automatic Passenger Counter	Continuous	30
	Fare Collection	Continuous	30

9.7.5 Failures and Fault Indications

Include circuitry in the LVPS to detect LVPS and battery charging failures:

1. The circuit shall transmit fault indications to the TOD and MDS via the vehicle's network.
2. See Section 17, Controls, Networks, and MDS, for design and submittal requirements.

9.8 Vehicle-to-Truck Wiring

For each wiring system on a truck, provide flexible cable connecting the vehicle and truck, with waterproof quick disconnect cable connectors as specified in Section 16, Materials and Workmanship, to facilitate removal of trucks:

1. Route cable to accommodate all truck motions without interference or excess strain.
2. Provide cable with strain relief on both the vehicle end and the truck end.
3. Flexible cable construction shall be selected for 30-year life under repeated flexing caused by truck motions.
4. Waterproof quick disconnect connectors shall be selected for the shock and vibration environment.
    a. Quick disconnect shall have no exposed live terminals.
    b. Removal of disconnect shall remove all hazardous voltages from its terminals.
5. Cabling to connectors on the truck side shall be restrained to prevent fatigue and chafing to the wiring or connectors.
6. Wire lengths, supports, and dress shall minimize strain at termination and support points under worst-case truck motions.
7. See Section 10, Propulsion System and Control, for additional requirements related to connection to traction motors.

9.9 Line Filters

9.9.1 General

Provide devices to perform the following filtering functions:

1. Protect vehicle equipment from line transients.
2. Filter ac voltage and currents impressed on the line by the propulsion system and all other systems fed by dc line voltage.
3. Suppress high-frequency voltage transients caused by converter or inverter switching operations.

9.9.2 Performance

Comply with the following:

1. Filters shall suppress all vehicle generated frequencies to the levels specified in Section 2, Design and Performance Criteria, under normal and abnormal equipment operation, at any location along the Project tracks:
    a. Prove through reliable simulations that the vehicle complies with the emission requirements for any allowable line voltage at any location and any combination of active and inactive substations.
    b. If the simulations are inconclusive, or cannot be performed to the full extent, include an EMI frequency monitor for all critical frequencies used by SEPTA.
2. The resonant frequency of each filter shall be less than 40 Hz and shall be inductive above 50 Hz.

9.9.3 Self-Test

Provide a line-filter self-test feature that operates during the power-up or power-down sequence:

1. If the tested capacitance value is outside of the allowed tolerance band, a failure message shall be sent to the MDS.
2. The detection of a failure shall not immobilize the vehicle, but upon detection of a failure, the power draw of the inverter with the defective filter shall be reduced by 50% until the defective condition is corrected.

9.9.4 Configuration

Line filters may be configured as follows:

1. As individual elements of various systems that are fed by high-voltage dc power; or
2. Combined, with the following limitations:
    a. If auxiliary power system is integral to propulsion inverter, they can share the input filters.
    b. Only line inductors may be shared; capacitor banks may not be shared.
    c. If line inductors are shared, system isolation switches or contactors shall be provided to permit independent operation of each provided system.

9.9.5 Components

9.9.5.1 Line Inductors

Comply with the following:

1. Thermal rating: Sufficient for maximum power dissipation under worst-case conditions specified in Section 2, Design and Performance Criteria.

2. Forced ventilation cooling: Allowed only if part of the inverter cooling. Standalone inductors shall be convection cooled.
3. Insulation and construction: Designed for the indicated service life in the specified environment.
4. Physical protection:
   a. Full enclosure; or
   b. Protected from physical damage by screens
5. Electrical connections: Environmentally sealed.
6. Standards:
   a. Construction and testing: Comply with IEC 60310
   b. Shock and vibration: Comply with IEC 61373, or other **approved** standard
7. Service life: 30 years.

9.9.5.2 Filter Capacitors

Comply with the following:

1. Capacitor life: Minimum 20 years, as used in this application.
2. Prohibited types: Electrolytic capacitors.
3. Location: Install in the same enclosure as the system's power components.
4. Bleeder resistor: Permanently connect across the terminals of each capacitor in the capacitor bank:
   a. Resistance: Select value to reduce voltage at the terminals of the capacitor bank to maximum 50 V within 3 minutes after high-voltage dc is removed from the bank.
   b. Traction inverter: Use the brake resistor to discharge the input filter capacitors when inverter is shut down.
5. Signage: Provide a permanent sign to warn maintenance personnel:
   a. Warning language: Lower the pantograph, wait 5 minutes, manually bleed, then short circuit the capacitor before commencing work.
   b. Sign location: Adjacent to the capacitors, visible when the door to the enclosure that houses the capacitor bank assembly is open.

9.10 Panelboards and Control Panels

Comply with the following:

1. Panelboards, control panels, circuit breakers, and related devices shall be rail industry proven.

2. Panelboards: Conform to NFPA 70 Article 408, Switchboards, Switchgear, and Panelboards, except as specifically specified otherwise or as **approved**.

3. Dead fronts: Moisture-proof, electrically insulating, laminated phenolic; or grounded metal.

4. Control panels:

    a. Conform to NFPA 70 Article 409, Industrial Control Panels, except as specifically specified otherwise or as **approved**.

    b. If a control panel contains circuit breakers, provide dead front(s) on the entire panel readily removeable for troubleshooting.

5. Power distribution to circuit breakers and switches shall be from a bus bar or bus circuit. Distributing power by successive or daisy-chained connections between device terminals is prohibited.

6. Provide minimum 10% spare space in each distribution panel but not less than one space for future circuit breakers for each voltage class, except provide minimum eight spaces for low-voltage dc in each of the vehicle's A- and B-sections. Provide covers for unused spaces.

7. Provide a nameplate for each breaker, switch, and indicating light:

    a. Lettering: Raised or recessed

    b. Required information:

        - Circuit designation
        - Operating voltage
        - Instructions such as "Do Not Operate Under Load" as appropriate

    c. Location: On the dead front

9.11 Fuses and Circuit Breakers

9.11.1 General

Fuses may be used only where specifically required or allowed in the Specifications, and where applicable circuit breakers are not commercially available. Fuse assemblies are subject to **approval**.

Each circuit breaker and fuse shall have a permanent label installed adjacent to the device.

9.11.2 Fuses and Fuse Holders

High-voltage dc fuses:

1. Provide totally enclosed fuse holders with no exposed high-voltage connections. When the fuse holder is opened, the fuse shall be extracted from the circuit and the exposed fuse safely isolated from any circuit connection.

2. Mount on the vehicle roof.

9.11.3 AC and Low-Voltage DC Circuit Breakers

Circuit breakers shall be rugged, fully suitable for the service intended, and of the highest quality procurable. Comply with the following:

1. Circuit breakers of the same rating shall be of the same manufacture and model throughout the vehicle.
2. A circuit breaker supplying continuous loads shall comply with the requirements of NFPA 70, Article 210.20, Overcurrent Protection, where “continuous load” and “listed” have the definitions given in NFPA 70 Article 100, Definitions.
3. Type: Molded case, DIN-rail mounted whenever possible.
4. Standards: Conform to UL 489, IEC 60077-1, and IEC 61373; IEC 60947-2 may be proposed in place of UL 489. Electronic components and subassemblies within the circuit breaker shall comply with IEC 60571.
5. Circuit breaker terminals shall not be used as junction points.

9.11.4 Circuit Breaker Prohibited Locations

Circuit breakers shall not be installed in the following locations, regardless of ventilation methods:

1. Within any location or arrangement that would permit accumulation of explosive gases near the breaker.
2. Within the low-voltage battery enclosures.
3. Within assemblies that may enclose the low-voltage battery enclosures.
4. In inaccessible locations that make maintenance difficult (access by removing only one panel is acceptable).
5. Publicly accessible locations.

9.12 Contactors and Relays

9.12.1 General

Comply with the following general requirements for both contactors and relays:

1. Document successful history of operation in rail transit control applications.
2. Mount and orient as recommended by the supplier.
3. Identify with the appropriate circuit designation. The label shall not be obscured by wiring or other equipment and shall not be mounted on relay covers, arc chutes, or other removable items.

4. Wire terminations: Comply with the requirements for wire terminations in Section 16, Materials and Workmanship.

5. Contacts:

   a. Current rating:

      - Based on continuous, inrush, or interrupting requirements, whichever is worse, and then derated by at least a factor of four.
      - Based on the worst condition of reduced surface contact which may result from tip misalignment during normal operation of the device.

   b. Material:

      - Selected for the actual loads, and not solely on the device rating.
      - Silver bifurcated contacts for low-level circuits and gold-alloy bifurcated-crossbar contacts for dry circuits.

   c. Series connected: Shall not be operated in circuits where the voltages and currents exceed the single derated contact ratings.

   d. Parallel connected: Not permitted.

6. Coils:

   a. Shall operate within the voltage range specified in IEC 60571.

   b. Shall have MOV suppression except where performance may be affected.

   c. Unsuppressed coils are permitted only with **approval**.

7. Indicator: Shall be equipped with a visual indicator of state that does not rely on direct observation of contacts.

9.12.1.1 Contactors

Comply with the following additional requirements for contactors:

1. Provide with series-fed arc-blowout coils.

2. Guaranteed mechanical service life: Minimum 5 million switching operations, except as **approved** where infrequent operation is expected.

9.12.1.2 Relays

Comply with the following additional requirements for relays:

1. Guaranteed mechanical service life: Minimum 10 million switching operations.

2. Contact rated electrical life: Minimum 500,000 operations, or 10 years, whichever is greater.

3. Time-delay relays: R-C or solid-state type. Mechanical or pneumatic time delay devices are prohibited.

4. Plug-in relays: Provide with a retainer that is captive to the relay socket. The retainer shall be arranged such that when released, contact cannot be made with energized adjacent circuitry.

9.13 Switches

9.13.1 High-Voltage DC Switches

High-voltage dc switches capable of manual operation are prohibited, except for the Shop switch.

High-voltage dc circuits shall be manually interrupted only as follows:

1. By activating the respective circuit breaker; or
2. By activating a low-voltage switch that subsequently controls a high-voltage contactor.

9.13.2 Low-Voltage Switches

Comply with the following:

1. Type: Industrial grade, rated at least IP66 in conformance with IEC 60529.
2. Use prohibited: Switches shall not directly control highly inductive or high inrush loads.
3. Contacts:
   a. Rating: Within manufacturer's recommendations for voltage and current, with current derated by at least a factor of four
   b. Type: Silver, double break
   c. Mechanism: Uses a wiping motion when contacts make or break
   d. Series connected: Shall not be operated in circuits where the voltages and currents exceed the single derated contact ratings
   e. Parallel connected: Prohibited
4. Switch bodies: Keyed to prevent rotation.
5. Mounting hardware: Metal, including the body portion extending through the panel.
6. Wire terminations: Comply with the requirements for wire terminations in Section 16, Materials and Workmanship.

9.14 Low-Voltage DC-DC Power Supplies

Comply with the following:

1. DC power supplies shall be high-efficiency, industrial-grade, switching supplies providing rated voltage and power over the full range of LVPS and battery voltage specified elsewhere.
2. Comply with IEC 61287.

3. Power supplies shall be commercially-available units from established power supply manufacturers, except where designed and integrated into specific systems.

4. Each power supply shall have the following protective features:

    a. Galvanic Input-to-output isolation of 1500 Vdc

    b. Short-circuit-proof output

    c. Automatic output current limiting

    d. Input and output overvoltage protection

5. Power supplies shall be powered from the vehicle's LVPS, with a dedicated circuit breaker for each in accordance with the requirements in this Section.

See Section 13, Vehicle Communication Systems, for requirements for the dedicated dc-dc power supply to power radio equipment.

9.15 Portable Device Charging

Comply with the following:

1. Vehicle LVPS shall power an adequate number of dc-dc power supplies to deliver power to the portable device charging stations specified in Section 14, Interior and Exterior Appointments.

2. Provide a dedicated circuit breaker for the protection of USB power circuits.

3. The USB power output shall be immune and isolated from any electrical noise present on the dc low-voltage network.

9.16 Contract Deliverables Requirements List (CDRL)

9-1	One-Line Power Distribution Diagrams
9-2	AC and DC Load Calculations
9-3	Arc-Flash Hazard Analysis
9-4	Safety Grounding Design Package
9-5	Ground Brush Design Package
9-6	Ground Fault Detection and Protection Design Package
9-7	Primary Power System Design Package
9-8	Pantograph Design Package
9-9	Shop Power Design Package
9-10	Auxiliary AC Inverter Design Package
9-11	Failure Management Design Package
9-12	DC Low-Voltage Power Supply Design Package
9-13	Low-Voltage Battery
9-14	Line Filters
9-15	Electrical Panels, Components, and Devices Design Package

9.17 CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested
5. Software functional descriptions: Include top level control parameters and values

9-1 One-Line Power Distribution Diagrams:

1. Include diagrams for each voltage level
2. The diagrams shall show loads, return current paths, protection, and grounds.

9-2 AC and DC Load Calculations:

1. Submit CDRL 9-1 before or at the same time as CDRL 9-2.
2. Include ac and dc load calculations in both normal and emergency (battery) modes.
3. Emergency loads shall include the emergency loads specified in this Section.
4. List the power for each load, assumptions used, and derating of loads, if any. Include wire sizes and breaker ratings. Include details of derating factors used for contactors and relays.
5. Include calculations showing loads that must be supplied during loss of a single auxiliary ac inverter. Furnish a narrative and schematics, as necessary, to demonstrate the ability of the system to power necessary loads.

9-3 Arc-Flash Hazard Analysis

1. Provide certification of compliance with IEEE 1584.
2. Submit the results of the ac and dc analyses in tables and include device or bus identification tag, bolted fault, and arcing fault current levels, flash protection boundary, distances, personal-protective equipment classes, and arc-flash incident energy (AFIE) levels.
3. Describe, when applicable, how worst-case fault conditions used in the analysis differ from worst-case bolted fault conditions.
4. Furnish a schedule of arc-flash hazard labels:
   a. Indicate each piece of equipment to be labeled.
   b. Include information that will be printed on each label.

9-4 Safety Grounding Design Package:

1. Furnish sufficient information to show the complete grounding scheme.
2. Data sheets for ground conductors and ground connections.
3. Ground path impedance for all ground paths.
4. Shop drawings showing routing of ground conductors.
5. Assembly drawings.

9-5 Ground Brush Design Package:

1. Description of the ground brushes
2. Calculations showing rms and peak current
3. Data sheets showing ratings of hardware
4. Hardware drawings
5. Assembly drawings showing ground brush arrangements and ground connections
6. Circuit diagram for both high-voltage dc current return and safety grounding showing physical current path
7. Impedance calculation for high-voltage ground wires between ground brushes and corresponding insulated ground pad

9-6 Ground Fault Detection and Protection Design Package:

1. Data sheets for hardware used
2. Sensitivity levels of each detection scheme
3. Assembly drawings
4. Wiring diagrams

9-7 Primary Power System Design Package:

1. High speed circuit breaker: Data sheets
2. Primary voltage fuses: Data sheets for fuses and associated components.
3. Surge arrester:
   a. Data sheets
   b. Rating selection design analysis

9-8 Pantograph Design Package:

1. Submit the pantograph dynamic envelope as a dedicated section in the design package.

2. Furnish sufficient information to verify that the pantograph does not lose contact with the OCS under specified normal and abnormal operating conditions.

3. Include the following:

   a. Data to support ratings of components
   b. Data sheets on each component
   c. Parts lists
   d. Electrical drawings
   e. Assembly drawings
   f. Recommended OCS contact force
   g. Adjustment range
   h. Graph of contact force over the full operating range

9-9 Shop Power Design Package:

1. Load calculations to support the ratings of the components, if not already submitted previously ("AC and DC Load Calculations")

2. Transfer switch design documentation:

   a. Dimensioned drawing of the switch itself identifying all components, including the manufacturer and part number(s), voltage and current ratings.
   b. Dimensioned outline drawing of the switch enclosure, including all connectors, operating handles, cover latches, mounting provisions.
   c. Details of sealing for all enclosure penetrations, including the cover.
   d. Enclosure materials and protective coatings.
   e. Dimensioned interior arrangement drawings of all components, including a plan view and all four side-elevations. Identify all components.
   f. Dimensioned physical location of the switch on the roof, showing distances/clearances to adjacent equipment, and maintainer accessibility to the plug and operating handle.

3. Data sheets on each major component, including but not limited to receptacle, receptacle enclosure, mating plug, and components used for interlocking

4. Electrical wiring diagrams and schematics for both power and control wiring showing functionality and interlocking

9-10 Auxiliary AC Inverter Design Package:

1. Functional description: Justify selected configuration and confirm compliance with requirements of this Section

2. Load study

3. Data indicating how the equipment operates under extreme conditions and faults

4. Assembly drawings

9-11 Failure Management Design Package:

1. List of critical safety and vehicle operation loads required during failure of an auxiliary ac inverter to maintain vehicle operation

2. Data sheets on transfer mechanism, if applicable

9-12 DC Low-Voltage Power Supply Design Package:

1. LVPS:

    a. Data sheets
    b. Capacity calculations showing ability to carry normal and transfer loads

2. Battery charging:

    a. Single LVPS (if proposed): Switch-over circuit functional description, data sheets for hardware, and electrical schematics

9-13 Low-Voltage Battery:

1. Battery description and specification

2. Recommended charging processes

3. Battery circuit breaker, including breaker data sheet, enclosure data sheet, location of enclosure, and electrical schematic

4. Load calculations and assumptions

5. Mounting location

6. Ventilation design

7. Battery heat detection system, including component data sheets, electrical schematic, and locations of components

8. Battery cut-out switch, including data sheet and location, if required by battery circuit breaker configuration

9-14 Line Filters

The following may be submitted as part of the CDRL for the respective system, if required elsewhere in the Contract Documents.

1. For each system filter:

    a. Frequency characteristics
    b. Component types, values, manufacturer
    c. Calculations demonstrating life expectancies
    d. Installation details, if not included within system enclosure

e. Filter degradation monitoring methods

2. Simulation results with sufficient information to demonstrate compliance with the Specifications.

3. EMI frequency monitor details, if simulation does not demonstrate compliance with Specifications.

4. Line filters not included with other system submittals:

   a. Data sheets showing ratings of hardware
   b. Functional description: Include failure detection
   c. Wiring diagrams

9-15 Electrical Panels, Components, and Devices Design Package:

1. Manufacturer's data: Include certification of compliance to specified standards or sufficient data to confirm compliance.

2. Location and application of each product submitted.

3. Shop Drawings:

   a. Panel layouts (front elevation, side elevations) as installed, with all components identified.
   b. Wire routing into the enclosure.
   c. Wire routing within the enclosure.
   d. Enclosure doors, showing accessibility to components with doors open.

9.18 Referenced Standards

The following standards are referenced in this Section:

APTA PR-E-RP-007-98	Recommended Practice for Storage Batteries and Battery Compartments
APTA PR-E-RP-009-98	Recommended Practice for Wire Used on Passenger Equipment
EN 50526-1	Railway applications - Fixed installations - D.C. surge arresters and voltage limiting devices – Part 1: Surge arresters
IEC 62485-2	Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries
IEC 62620	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications
IEC 60077-1	Railway applications - Electric equipment for rolling stock - Part 1: General service conditions and general rules

IEC 60077-3	Railway applications - Electric equipment for rolling stock - Part 3: Electrotechnical components - Rules for d.c. circuit-breakers
IEC 60310	Railway applications - Traction transformers and inductors on board rolling stock
IEC 60529	Degrees of Protection Provided by Enclosures
IEC 60571	Railway applications - Electronic equipment used on rolling stock
IEC 60947-2	Low-voltage switchgear and controlgear - Part 2: Circuit-breakers
IEC 61287	Railway applications - Power converters installed on board rolling stock
IEC 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
IEEE Std 16	Standard for Electrical and Electronic Control Apparatus on Rail Vehicles
IEEE 1476	IEEE Standard for Passenger Train Auxiliary Power Systems Interfaces
IEEE Std 1584	Guide for Performing Arc Flash Hazard Calculations
NFPA 70	National Electrical Code
NFPA 70E	Standard for Electrical Safety in the Workplace
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems
UL 489	Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

END OF SECTION

Table of Contents

10.1 General

10.1.1 Scope

Provide traction inverters, traction motors, dynamic brake resistors, drive gear units, sensors, control logic, friction brake blending logic, wheel slip/slide correction, protection devices, and all accessories necessary to meet the specified requirements of propulsion and dynamic braking.

10.1.2 System Configuration

Comply with the following configuration requirements:

1. Configure each propulsion system to function independently, regardless of the condition of other propulsion systems.
2. Sharing of components between propulsion systems shall be minimized, and only as **approved**.
3. Provide either one inverter per powered truck or one inverter for each motor.
4. Power collection and primary protection equipment (see Section 9, Electrical Equipment) may be shared between the propulsion systems on a vehicle.
5. The propulsion system shall meet the hardware, software, and system requirements specified in Section 18, Systems and Software Engineering

10.1.3 Propulsion Control Signals

See Section 17, Controls, Networks, and MDS, for propulsion system control signal requirements.

10.1.4 Inverter Drive Technology

Comply with the following:

1. Propulsion and dynamic braking: Use state-of-the-art IGBT (insulated-gate, bipolar-transistor) inverters. Newer designs may be proposed, that use silicon carbide based semiconductors.
2. Brake chopper: Use a high-side IGBT switching device and a freewheeling diode across the brake resistor.
3. Drive control system: Use a modern vector control system, with sufficient accuracy to produce stable operation at any speed down to standstill, including the ability to maintain the vehicle stationary on a grade.

10.1.5 Drive Configuration

Comply with the following:

1. Powered trucks: Each motor shall drive one axle or one wheel unless otherwise **approved**.

2. Drive configuration:

    a. Proven in similar service

    b. Minimizes unsprung weight on the drive axles or wheels

10.1.6 Interchangeability

Propulsion system components shall be identical and interchangeable between trucks and all vehicles.

10.1.7 Circuit Protection

See Section 9, Electrical Equipment.

10.2 Equipment Thermal Capacities

The thermal capacity of the propulsion equipment shall be based on either the normal duty cycle or the abnormal duty specified in Section 2, whichever is worse.

10.3 Equipment Temperature Management

Comply with the following:

1. Provide equipment cooling on a per-truck basis such that continued operation is possible via the remaining propulsion system, at proportionally reduced performance, if the cooling system fails.

2. Comply with equipment temperature requirements in Section 9, Electrical Equipment.

10.4 Transients and EMI

10.4.1 Switching Line Transients

Comply with the following requirements:

1. Suppress switching line transients normally generated by the propulsion system such that the instantaneous voltage complies with IEC 60850.

2. Vehicle-borne equipment shall withstand vehicle and wayside generated transients without damage or reduction in life (see Section 2, Design and Performance Criteria, for required tolerance to transients and abnormal electrical conditions).

10.4.2 Electromagnetic Interference

Comply with the following:

1. Propulsion system shall not exceed electromagnetic interference (EMI) limits, as specified in Section 2, Design and Performance Criteria, in any mode, including regenerative braking and abnormal operating conditions. See Fault Detection section, below, and also Section 9, Electrical Equipment, for line-filter monitoring.

2. Propulsion system shall operate successfully in an environment of high ambient electrical noise, whether self-generated, generated by other vehicle systems, or generated off-vehicle.

10.5 Performance Requirements

Comply with the requirements specified in Section 2, Design and Performance Criteria.

10.6 Propulsion System Functions

10.6.1 Load Compensation

Normal Operation: The propulsion control system shall adjust tractive and braking efforts to compensate for varying passenger loads as specified in Section 2.7.3, Design and Performance Criteria. See also Section 12.3.3, Friction Brake System.

Failure Mode: If the load compensation signal fails, the system shall default to the load value of the nearest healthy truck, and notify the Operator through the MDS system (see Section 17, Controls, Networks, and MDS).

10.6.2 Not Used

10.6.3 Vehicle Wash Mode

Comply with the following:

1. Provide a vehicle wash mode to enable the Operator to maintain proper speed through the vehicle wash facility.
2. The vehicle wash mode, when activated, shall smoothly limit the speed of the vehicle. This speed shall be initially set to 8 km/h (5 mph) and be adjustable by SEPTA by use of a PTU or equivalent method.
3. The vehicle wash mode shall be activated and canceled by a control on the Cab Console. It shall be necessary for the Master Controller key switch to be in the On position for the vehicle wash mode to be activated.
4. It shall be necessary for the vehicle to be stopped and the Master Controller handle to be in the Full Service Brake or the Maximum Brake position for the vehicle wash mode to be canceled, except that the vehicle wash mode shall be automatically canceled when the Master Controller key switch is moved from the On position.
5. Once the vehicle wash mode is activated, all the external ventilation fans used on the vehicle shall be deactivated to limit the ingress of water.

10.6.4 Towing Mode

The propulsion system shall configure itself for operation in towing mode when the CBTC Towing Mode switch is enabled, as per Section 5, Operator’s Cab Controls, and Section 21, Communications Based Train Control.

10.6.5 Braking

10.6.5.1 Friction Brake Control

The propulsion control system shall interface directly with the friction brake controls to optimize blending, slide control, and failure management.

10.6.5.2 Dynamic Braking

Comply with the following:

1. Type: Combined regenerative and rheostatic braking.
2. Operating range: Continuously available from vehicle design speed down to a vehicle speed of 5 km/h (3 mph) or less.
3. Zero speed: Friction brakes shall be fully blended in to ensure a secure zero speed detection.
4. For brake initializations below 5 km/h (3 mph), the dynamic brake shall be disabled.
5. The dynamic brake control system shall perform the following:
    a. Continuously monitor line voltage.
    b. Supply to the line the maximum amount of energy possible within the line-voltage limits specified in Section 2, Design and Performance Criteria.
    c. Divert to the braking resistors only that generated energy in excess of the energy accepted by the vehicle auxiliary loads and the line.
6. No line voltage: Once initiated, dynamic braking shall be available independent of the presence of line voltage.
7. Friction brake coordination: Provide a per-truck dynamic brake effort signal to the friction brake system, indicating achieved dynamic brake effort. Coordinate signal characteristics and values with the friction brake supplier.
8. Regenerative braking:
    a. Maximum voltage: 800V
    b. Possible to cut out by PTU and by a sealed switch for test purposes.
9. CBTC Braking Enforcement
    a. The Propulsion System shall coordinate with the Friction Braking System, as indicated in Section 12, Friction Brake System, to enforce braking events originating from the CBTC system, including such elements as blended brake and propulsion power-cut.
10. Collision Avoidance System Braking Enforcement

a. The Propulsion System shall coordinate with the Friction Braking System, as indicated in Section 12, Friction Brake System, to enforce braking events originating from the Collision Avoidance System, including such elements as blended brake and propulsion power-cut.

10.6.6 Fault Detection

10.6.6.1 General

Provide a comprehensive fault detection and health monitoring system, on a per-inverter basis:

1. The system shall detect and report the following:

   a. Actual and pending equipment failures

   b. Out-of-range voltages or signals

   c. Loss or reduction of requested power/braking efforts or performance; and similar problems

2. Record detected faults in local fault logs, and report to the MDS. See also Section 17, Controls, Networks, and MDS.

3. System health monitoring shall identify excess EMI. See also Section 9, Electrical Equipment, Line Filters section and see Section 2, Design and Performance Criteria, for individual subsystem EMI compliance.

10.6.6.2 Dynamic Brake Fault

Comply with the following:

1. Design of dynamic brake failure detection and associated interface circuits:

   a. Conform to the general safety design requirements specified in Section 2, Design and Performance Criteria.

   b. Minimize nuisance fault annunciations due to transient events, including momentary loss of primary power when braking is initiated.

2. Performance: When failures in dynamic braking are detected, the system shall perform the following:

   a. All residual dynamic brake effort shall be disabled

   b. The dynamic brake signal to friction brake shall be clamped to zero

   c. A dynamic brake fault shall be indicated for that truck

10.6.6.3 Fault Annunciation

Comply with the following:

1. Provide visual annunciation in the cab via the MDS for all propulsion system faults, as specified in Section 17, Controls, Networks, and MDS, including but not limited to the following:

a. Cutout

b. Dynamic brake failure

c. General faults

d. Ventilation failure

e. Overheating

f. Line voltage out of range

2. Interface with CBTC as specified in Section 21, Communications Based Train Control, to provide propulsion fault status for any degraded propulsion mode to the CBTC system so that degraded mode acceleration and braking effort can be calculated.

10.6.6.4 Reduced Overspeed Set Point

Propulsion system faults may impose a reduced overspeed set point, as appropriate (see Overspeed Protection section, below).

10.6.7 Energy Management

Comply with the following:

1. Propulsion system shall measure the total energy consumed by the vehicle by measuring high-voltage input voltage and current drawn by propulsion and auxiliary system and report to the MDS. Measure the following:

   a. Total energy consumed by the vehicle

   b. Total energy regenerated to the OCS

   c. Total energy consumed by auxiliaries

2. Alternatively, a separate energy management system able to monitor and report the energy consumption to MDS by propulsion and auxiliary subsystems may be proposed.

10.6.8 Direction Change

The inverter control shall perform as follows regarding direction change:

1. Respond to cab reverser switch trainlined direction control signals only when no-motion is detected, and tractive effort is zero.

2. Monitor correspondence between the trainline command and motor rotation, and if out-of-correspondence, apply friction brakes and flag a rollback condition.

3. Comply with additional requirements in Section 5, Operator’s Cab Controls.

10.6.9 Rollback Prevention

The propulsion system shall detect and prevent vehicle motion in a direction opposite to that selected by the cab when a propulsion mode is selected, as specified in Section 2, Design and Performance Criteria.

10.6.10 Cutout Control

Include provisions for each powered truck to be independently isolated from the propulsion control signals and the OCS supply:

1. With one truck cut out on a single vehicle, it shall be possible to operate the vehicle in either direction over the whole alignment with no damaging effects.

2. If needed, a speed limit may be automatically applied when any truck is cut out (see Overspeed Protection, below).

3. All other systems shall remain operational.

10.6.11 Wheel Slip/Slide Detection and Correction

Provide a wheel spin/slide detection and correction system as specified in Section 2, Design and Performance Criteria, as an integral part of the propulsion control system:

1. Coordinate system with friction brake slide control in Section 12, Friction Brake System.

2. The propulsion system shall exchange wheel-slip and wheel slide status with the CBTC system, as specified in Section 21, Communications Based Train Control, to allow CBTC to adjust propulsion commands as-needed.

10.6.12 Overspeed Protection

The propulsion control system shall include overspeed protection that limits vehicle speed to set values, up to but not exceeding maximum operating speed, by means of tractive effort and brake control. See the Speed Sensing Devices section, below.

1. Overspeed protection shall function as follows:

    a. As overspeed set point is approached: Limit propulsion effort as a function of speed.

    b. At overspeed set point: Reduce tractive effort to zero.

    c. At 6 km/h above overspeed set point:

        - Impose a full service brake command.

        - The brake command shall be resettable by moving the Master Controller to the full service brake position at any speed below the overspeed set point.

2. Overspeed set point:

    a. Initial: Set per values defined in Section 2, Design and Performance Criteria, Speed Requirements section.

    b. Changes: Setpoints shall be adjustable by SEPTA, up to and including the maximum operating speed in Section 2, Speed Requirements section.

3. Abnormal operating conditions: Overspeed set point and reset criteria may vary as deemed necessary to protect equipment in case propulsion or brake equipment is in failure mode or has been cut out, as **approved**.

4. Equipment protection: The propulsion system may impose a separate, non-user-adjustable, overspeed setting for equipment protection, set no lower than the vehicle design speed value in Section 2, in Speed Requirements section.

5. CBTC shall have the capability to impose an overspeed set point as specified in Section 21, Communications Based Train Control. The propulsion system shall be equipped with appropriate interfaces to permit reception, acknowledgement, and enforcement of this overspeed limit.

10.6.13 Adjustments for Wear

Adjustments shall not be necessary to compensate for component wear, aging, and similar phenomena:

1. Provide compensation for a reference wheel diameter using software commands from Portable Test Units.

2. Adjustments shall be made in 1 mm (0.04 in) increments of wheel diameter, covering the full range between new and fully worn diameters.

3. Other required wheel size compensation shall be automatic.

4. It shall be possible to query actual wheel diameters for each axle/wheel on the MDS as specified in Section 17 Controls, Networks, and MDS.

10.6.14 Distance Signal

Comply with the following

1. As required by the system design, provide a distance signal with sufficient accuracy to the following systems specified in Section 13, Vehicle Communication Systems:

   a. Automatic passenger information

   b. Automatic passenger counting

   c. Any other system as required – See Section 5, Operator’s Cab Controls paragraph 5.6.1 #3

10.7 Propulsion Control Networks

Provide a data diode between propulsion control network (PCN) and any other networks to permit one-way data traffic and allow secure transmission of propulsion health status to systems outside of the PCN. This will address the cybersecurity requirements for isolating the PCN network in Section 17, Controls, Networks, and MDS; alternate cybersecure solutions may be proposed for **approval**.

10.8 System Components

10.8.1 Traction Motors

AC traction motors shall have the following basic design features:

1. Motor Type: Three-phase, squirrel cage induction motor, with welded or brazed copper cage and formed stator coils.

2. Ventilation: Forced-ventilated or self-ventilated.

3. Duty: Thermally rated in accordance with the duty-cycle specified in Section 2, Design and Performance Criteria.

4. Load Sharing: The motor characteristics shall allow achievement of all performance requirements with wheel diameter differences of at least 0.6% for motors driven in parallel by the same inverter.

5. Motor Standard: IEC 60349-2.

6. Insulation:

    a. Motor insulation: IEC 60085, Class 200 insulation system or better.

    b. Motor stator coils: Vacuum pressure impregnated in the complete stator frame assembly.

7. Enclosure: Splash-proof or totally enclosed.

8. Mounting:

    a. Each traction motor shall be resiliently or rigidly mounted to the truck frame. Axle-hung motors are prohibited.

    b. Unsprung mass of the motor-gear unit assembly shall be kept to a minimum.

    c. Provide safety straps, tabs, or hangers as required to retain the motor or gear if the mount fails.

9. Shaft Coupling:

    a. Provide a maintenance-free coupling arrangement between traction motor and gear-unit shafts.

    b. The coupling design and motor-gear unit mounting arrangement will be considered acceptable if no maintenance is required and coupling life exceeds drivetrain overhaul period.

10. Motor Design Speed:

    a. Equal to the propulsion and braking design speed specified in Section 2, at fully worn wheels.

    b. Based on the motor design speed, test the traction motor to the overspeed defined in IEC 60349-2.

11. Bearings:

    a. Type: Grease lubricated, antifriction bearings:

        - Grease cavities: Large enough to hold a five-year supply of lubricant. Grease cavities shall be adequately sealed to prevent the ingress of contaminants.
        - Access to the grease fittings shall be possible without removing the trucks from the vehicle body
        - Configurations are acceptable that use gear lubricant for the traction motor bearing at the pinion end.
        - Ball bearings, if used, shall be rated according to ANSI/ABMA 9.
        - Roller bearings, if used, shall be rated according to ANSI/ABMA 11.

    b. ABMA L10 rating life: Equivalent to 1,600,000 km (994,200 mi) of service, or greater.

    c. Inspection or service: None required except periodic lubrication.

    d. Prevent induced shaft currents and electrostatic discharges resulting from inverter switching pulses from damaging motor bearings as follows:

        - Provide insulated bearings, shaft grounding brushes, microfiber-type shaft grounding rings, or a combination of these measures.
        - Demonstrate that the proposed solution has been used successfully for minimum five years in a similar transit environment.

12. Motor and Rotor Balance:

    a. Motors shall be dynamically balanced to meet the requirements of IEC 60349-2.

    b. Balancing shall be accomplished by using metal weights, welded in place; or by drilling the rotor core.

13. Vibration: Meet the requirements of IEC 60349-2.

14. Noise: Motor shall be free of objectionable windage and mechanical noises at all vehicle speeds and under all load conditions.

15. Markings: Terminals, leads, and motor frames shall be clearly marked for positive identification.

16. Traction Motor Wiring and Electrical Connections:

    a. Cabling shall minimize EMI to meet EMI emissions requirements in Section 2, Design and Performance Criteria:

        - As a minimum, provide a ground wire connecting inverter ground to traction motor ground, bundled with the three-phase cables.
        - There shall be no other ground connection of this cable between inverter and traction motor.

- Shielded traction motor cabling may be proposed if three-phase cable bundling does not minimize EMI to acceptable levels.

b. Size cables in accordance with NFPA 130, Section 8.6.3, Propulsion Motors.

c. Connectors to motor leads and related hardware:

- Quick-disconnect type
- Rated for the peak voltages and currents present

d. See Section 9, Electrical Equipment, for vehicle-to-truck wiring requirements.

10.8.2 Gear Drive

Gear units shall have the following basic design features:

1. Gear units shall be service-proven and capable of satisfactory operation with the proposed traction motors while conforming to the performance levels specified in Section 2, Design and Performance Criteria.

   a. Unless otherwise **approved**, gear units shall be directly connected to the traction motors using parallel drives.

   b. The gear units shall be arranged to provide resilient attachment either to the truck frame or to the traction motor.

2. Bearings: Provide anti-friction bearings throughout:

   a. Inspection or service: None required before a major gearbox overhaul.

   b. ABMA L10 rating life: Equivalent to minimum 1,600,000 km (994,200 mi) of service.

   c. External bearing shaft seals shall be the labyrinth type, with supplemental sliding contact seals, if necessary to keep high velocity splashed water from entering the gear units.

3. Lubrication:

   a. Oil lubricated: Gear unit shall have sufficient baffles, dams, and passages to ensure adequate flow of lubricant to bearings and gears under all combinations of acceleration, speed, direction, load, and environment.

   b. Moisture: Prevent infiltration into the lubricant from any and all sources.

   c. Oil replenishment: Maximum rate of one quart for every 160,000 km (99,400 mi).

   d. Filling and draining:

   - Provide openings with removable plugs located for easy access.
   - Plugs shall be of a type or be located to prevent damage by obstacles on the track and the resultant loss of lubricant.
   - Plugs shall be secured by lock wires, lock tabs, or other **approved** means to prevent loosening in service.

- Filler plug: Opening shall be arranged to give an indication of oil level and prevent overfilling.
- Drain plugs: Shall have magnetic particle collectors.

4. Maintainability and Life:

   a. Accessibility: Provide inspection covers on the gear housing that are accessible, removable, oiltight, and airtight for visual inspection of the gears.

   b. Inspection or service before a major overhaul: None requiring disassembly. See Section 2, Scheduled and Preventive Maintenance section, for the minimum operating miles to the first major overhaul.

   c. Life: Minimum 1,600,000 km (994,200 mi).

5. Elastomeric Coupling: Provide an elastomeric axle coupling that couples the gear unit output to the axle and suspends the mass of the gear unit from the axle.

   a. Service Life: At least 640,000 km (400,000 mi) or ten (10) years, whichever comes first.

   b. Lubrication: Shall not be required

   c. Clearance: The coupling design shall provide sufficient clearance between the axle and the inside of the gear unit output quill to prevent contact between them with one wheel of a truck raised 2 in (50 mm) with a vehicle weight from AW0 to AW4.

   d. Heat Shielding: The elastomeric elements shall be shielded from heat radiation from friction brake discs as necessary to ensure that the elastomeric elements meet the minimum service life.

   e. Maintainability: All critical parts of the coupling shall be visible for inspection without disassembly or removal of any part.

10.8.3 Resistors

10.8.3.1 Dynamic Brake Resistors

Comply with the following:

1. Capacity: Sufficient to enable full power dissipation by convection cooling during operation at full service brake over the Project alignment up to and including AW3 passenger loading:

   a. Assume no regeneration into the line.

   b. Do not consider air speed in estimating resistor cooling for resistor designs.

2. Cooling: Either convection-air ventilated or forced-air ventilated:

   a. Forced-air cooling is acceptable only if the inverter cooling air is used.

   b. Standalone resistors shall be convection cooled.

c. In either case, exhaust air and radiated heat from the resistors shall be routed to prevent damage to nearby equipment and overhead contact wires.

d. Select the cooling method for the brake resistor to achieve necessary heat dissipation and minimize maintenance.

3. Location: Roof mounted.

4. Resistor grid:

   a. Resistor type: Edge wound ribbon, flat wound ribbon, or stamped sheet metal types.

   b. Application design: Conform to NFPA 130, Section 8.6.5, Propulsion and Braking System Resistors.

   c. Standard: Design and test per IEC 60322 requirements for double-insulated applications, except both insulation levels shall be rated at the basic insulation level.

   d. Grid expansion: Make provisions to prevent warping.

   e. Maximum active element temperature under specified operating conditions shall be limited to the manufacturer's recommendation.

5. Protection:

   a. Shield resistors from accumulation of snow and ice.

   b. Provide screens to protect resistors from persons working on the roof, physical damage (including that resulting from overhead vandalism), and fouling by debris. Screens shall withstand all brake resistor temperatures without damage or distortion. The resistor protective screens shall not deform if walked on by maintenance personnel.

6. Material:

   a. Resistor elements, resistor frames, heat shields, screens, enclosures, and hardware shall be stainless steel.

   b. All resistor components shall be selected both for their thermal and mechanical properties and for corrosion resistance.

   c. Mounting and grid insulators shall be designed for rail application and withstand weather, heat cycles, and vibration encountered in this application for the design life of the vehicle.

10.8.3.2 Other Resistors

Other power resistors shall have power dissipation capability that is 50% greater than the maximum load to which they can be exposed under all specified operating conditions.

10.8.4 Contactors

Comply with the following:

1. Minimize the use of contactors for propulsion control to the greatest possible extent.

2. Comply with contactor requirements in Section 9, Electrical Equipment.

3. Propulsion system contactors, in coordination with HSCB, shall be capable of safely interrupting the maximum possible load current in the event of a malfunction.

4. Safe and continued operation shall be possible upon reset after a malfunction.

5. Coordinate contactor rating and operation with circuit protection elements.

10.8.5 Propulsion Line Filter

Line filter(s) shall conform to the requirements of Section 9, Electrical Equipment.

10.8.6 Traction Inverter

Traction inverter shall comply with the design requirements of Section 2, Design and Performance Criteria.

10.8.7 Control Logic

10.8.7.1 General Requirements

Propulsion system control shall comply with the design requirements of Section 2, Design and Performance Criteria, Section 17, Controls, Networks, and MDS and IEC 60571.

10.8.7.2 Configuration

Provide dedicated control logic units and logic power supplies for each propulsion system such that a failed system has no impact on other units.

10.8.7.3 Monitoring

The control logic units shall indicate status and perform fault recording as part of a comprehensive MDS in accordance with Section 17:

1. Critical parameters: Continuously monitor motor currents, switching device currents, cooling air flow, and component temperatures.

2. Detection and response times: Shall permit detection and corrective action on a per unit basis before other protective devices, including the HSCB, react.

10.8.7.4 Self-Tests

The control logic shall support two types of self-tests. The self-tests shall be initiated automatically and manually through the PTU and MDS, in accordance with Section 17, Controls, Networks, and MDS, and as **approved**.

1. Low-voltage test: Checks the integrity of the control logic and the peripheral low-voltage circuits.

2. High-voltage test: Checks all high-voltage components of the propulsion system and identifies malfunctioning high-voltage components or components out of tolerance such as filter capacitor,

filter inductor, or resistor. See Section 9, Electrical Equipment, for additional input filter capacitor test result requirements.

10.8.8 Static Power Devices

Comply with the following:

1. Apply and install per manufacturer's recommendations.
2. Propulsion power semiconductor assemblies shall be functionally grouped, keyed, and mounted in modular form to facilitate maintenance and easy removal.
3. Ventilation:
    a. Forced air may be used where required to stabilize heat sink temperature, but shall not be used to ventilate the inside of the equipment cabinets.
    b. Route cooling air through channels free of high voltage.
    c. See also Section 9, Electrical Equipment, for equipment temperature management requirements.

10.8.9 Line Contactor

Provide a line contactor for each inverter to make and interrupt power during normal or faulted conditions and to isolate the inverter from primary power when the inverter is cut out:

1. Type: Contactor shall comply with Section 9, Electrical Equipment.
2. Operation: Coordinate with the high speed circuit breaker (HSCB) specified in Section 9.
3. Protection: Coordinate line contactor rating with inverter protection requirements.
4. Instantaneous inrush currents:
    a. Provide a charging circuit to limit inrush current to acceptable values.
    b. The charging circuit shall not interfere with vehicle performance under conditions of intermittent line-voltage availability, as with an icy contact wire or pantograph bouncing.
    c. See also the Line Filters section in Section 9.

10.8.10 Speed Sensing Devices

Provide speed sensors to measure axle or wheel speeds:

1. Location: On the axles or wheel assemblies, or incorporated as integral with traction motor or gearbox if higher resolution is desired.
2. Quantity: Sufficient to continue normal operation with one speed sensor failed on each powered truck.

3. Sensor type:

    a. Active or passive magnetic pick-up type.

    b. Optical encoders may be used only with **approval**.

4. Sensor packaging:

    a. The face of each speed sensor shall be smooth with no protruding elements.

    b. The sensor shall be hermetically sealed in a stainless steel case.

    c. The face shall be encased in a seamless stainless steel cover unless the sensor is guaranteed, and proven in service, to be immune to damage or inaccurate operation caused by continuous exposure to the intended lubricating fluids and temperatures.

5. Interchangeability: Speed sensor types and mountings shall be identical between powered trucks and within the non-powered truck.

6. Mounting:

    a. Mechanical adjustments are prohibited when mounting speed sensing devices.

    b. The mounting method shall be selected to guarantee that the speed-measuring device cannot indicate speeds other than the actual axle speed under all conditions.

7. Accessibility: All speed sensors shall be easily accessible for inspection and replacement both with trucks attached to vehicles over maintenance pits; on jacks; and with trucks sitting by themselves on the floor.

8. Wiring:

    a. Speed sensor wiring shall be enclosed in conduit on the vehicle body and shall be run to a terminal box that is located above the speed sensor location on the truck.

    b. Speed sensors shall be connected to the vehicle body by shielded wires terminated in waterproof multi-pin connectors. See Section 16, Materials and Workmanship, for cable connector requirements.

9. CBTC speed sensors: Provide mounting locations for CBTC speed sensors as specified in Section 21, Communications Based Train Control, in locations distinct from propulsion speed sensors and AVL speed sensors.

10. AVL speed sensors: Provide mounting locations for AVL system dead-reckoning speed sensors at each end of the vehicle, as specified in Section 13, Vehicle Communication Systems, in locations distinct from propulsion speed sensors and CBTC speed sensors.

10.9 Inverter Enclosures

Comply with the following:

1. The sections of the inverter enclosure containing sensitive electronics and control components shall be IP66 rated. An internal fan may be used to stir internal air to avoid hot spots.

2. The external air circulation area containing heat sinks, line filter chokes, and brake resistors may be IP20 rated.

3. Provide ventilation where necessary as follows:

   a. Semiconductor heat sinks, line-filter chokes, brake resistor, and contactors, if they are designed to interrupt power.

   b. Openings to the atmosphere shall be screened and filter-protected.

   c. Filter elements shall prevent snow and water from entering the enclosure.

   d. Filters shall have a replacement interval greater than two years.

10.10 Painting

Comply with the following:

1. Traction motors and gear reducers: Same paint as specified for the truck, applied by either the manufacturer or the Contractor.

2. Requirements: See Section 16, Materials and Workmanship.

3. Color: See Section 14, Interior and Exterior Appointments.

10.11 Contract Deliverables Requirements List (CDRL)

10-1 Propulsion System Design Package
10-2 Inverter Design Package
10-3 Run Time Simulations
10-4 Traction Motor Design Package
10-5 Gear Drive Design Package
10-6 Brake Resistor Design Package
10-7 Control Logic Design Package
10-8 Interface with Friction Brakes Design Package
10-9 Fault Monitoring Design Package

10.12 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

5. Software functional descriptions: Include top level control parameters and values

6. Line replaceable unit (LRU) list and lowest line replaceable unit (LLRU) list

10-1 Propulsion System Design Package:

1. Propulsion and drive system configuration

2. High-voltage system and grounding schematics

3. Primary power and traction motor cabling

4. Outline drawings of major components

5. Cooling air requirements, filtering, and blowers

6. Manufacturer, part number, and ratings of power semiconductors

7. Line reactor details

8. Filter capacitor details

9. Overvoltage and overcurrent protection concept

10-2 Inverter Design Package:

1. Data sheets and a layout drawing

10-3 Run Time Simulations:

1. Perform at AW3 loading over the Project alignment:

   a. Assume nominal OCS voltage

2. Normal Duty:

   a. Use maximum available: acceleration and service braking rates
   b. Operate until equipment temperatures stabilize, but no less than one complete round trip
   c. Stop at all passenger stations for 30 second dwell
   d. Stop at 20% of traffic lights for 15 second dwell
   e. Operate up to posted civil speed limits

3. Abnormal Duty:

   a. Selected abnormal duty cycle from Section 2, Design and Performance Criteria.
   b. Use maximum available: acceleration and service braking rates
   c. Stops as defined by Normal Duty, above, except as limited by abnormal duty definitions
   d. Operate up to posted civil speed limits, except as limited by abnormal duty definitions.

4. Simulation results: Provide a report showing simulation results of Normal and Abnormal duty cases. Include the following in the report:

   a. Input assumptions.

b. Ambient and initial equipment temperature assumptions.
c. Predictions of operating temperatures for cited components, at the worst-case ambient temperatures in their installed environment (may be higher than the open-air ambient temperatures in Section 2, Design and Performance Criteria).
d. Acceptance criteria, such as maximum permitted temperatures, for all devices.
e. Simulation graphs using distance as the x-axis and indicating, at a minimum, all station-stop locations:

   - Inbound and outbound trips on separate graphs
   - Speed/time/distance plots, including civil speed limits
   - Temperature of motor windings, brake resistors, input filter inductor, inverter and brake chopper devices.

f. Verification of the thermal capacity of the propulsion system under Normal and Abnormal duty cycles
g. Level of braking assumed in degraded modes.
h. Maximum temperature predictions (or actual test results) for all equipment, including motor windings, brake resistors, inverter and brake chopper device junction temperatures, and similar.

5. Thermal Capacity Calculations:

   a. Verification of the thermal capacity of the propulsion under the specified duty cycle.
   b. Input assumptions.
   c. Ambient temperature assumptions.
   d. Level of braking assumed on extended downgrades in degraded modes.
   e. Speed/time/distance plots of the vehicle on the Project alignment.
   f. Temperature predictions (or actual test results) for all equipment, including motor windings, brake resistors, inverter and brake chopper device junction temperatures, and similar.

10-4 Traction Motor Design Package:

1. Tractive effort curves as a function of rpm, including as a minimum the following signals:

   a. Torque
   b. Output power
   c. Phase voltage
   d. Phase current
   e. Efficiency
   f. Stator frequency
   g. Slip frequency

2. Outline drawings of major components

3. Insulation process information

4. Data sheets with sufficient information to confirm that all specified requirements are satisfied, such as the following:

    a. Nominal values of signals listed in Item 1, above
    b. Peak values of signals listed in Item 1, above

10-5 Gear Drive Design Package:

1. Outline drawing and data sheets

2. Traction-gear drive coupling

10-6 Brake Resistor Design Package:

1. Data sheets

2. Resistor outline drawing

3. Resistor grid and frame drawing showing electrical isolation and protective screens

4. Rationale for the selected cooling method supported by brake resistor temperature rise analysis

10-7 Control Logic Design Package:

1. Description of vehicle control logic functionality, including a functional block diagram of the application program

2. Interfaces with the vehicle data bus and hard-wired control signals

3. Diagnostic features

4. Self-test capabilities

10-8 Interface with Friction Brakes Design Package:

1. Description of the interface between the propulsion system control logic and friction brake controls

2. Description of CBTC and Collision Avoidance System braking enforcement interfaces with propulsion, including blended brake and power-cut.

10-9 Fault Monitoring Design Package:

1. Description of the propulsion system fault monitoring scheme and response performance that supplements the MDS CDRL in Section 17, Controls, Networks, and MDS.

10.13 Referenced Standards

The following standards are referenced in this Section:

ANSI/ABMA 9	Load Ratings And Fatigue Life For Ball Bearings

ANSI/ABMA 11	Load Ratings And Fatigue Life For Roller Bearings
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60322	Railway applications - Electric equipment for rolling stock - Rules for power resistors of open construction
IEC 60349	Electric traction - Rotating electrical machines for rail and road vehicles
IEC 60349-2	Electric traction - Rotating electrical machines for rail and road vehicles- Part 2: Electronic converter-fed alternating current motors
IEC 60571	Railway applications - Electronic equipment used on rolling stock
IEC 60850	Railway applications - Supply voltages of traction systems
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems

END OF SECTION

Table of Contents

11.1 General

11.1.1 Scope

This Section specifies the design and functional requirements of the truck assembly, which includes truck frame and suspension components, wheels and axles, and other components defined below.

Gearboxes, motors, wiring, and brake system components are physically part of the completed truck assemblies but are not included in this Section, except that mechanical interfaces requiring welding or drilling on the truck frame shall be considered part of the truck.

11.1.2 General Requirements

Comply with the following:

1. The City and Suburban Divisions may require different truck components, such as wheels and axles. This shall be determined prior to NTP. Otherwise, as much as possible the truck and its components shall remain interchangeable between the two divisions. Where differences are required, the component shall be clearly marked as City or Suburban division only. All differences shall be submitted for **approval**.

2. Supplier experience: The trucks shall be designed, and the truck frames manufactured by a supplier that has designed and manufactured the same trucks previously for the vehicle offered:

    a. Adaptations are limited to changes in dimensions, materials, or procedures necessary to comply with the Specifications.

    b. The trucks shall have operated in the same or more unfavorable climatic conditions over track meeting FRA Class 4 requirements, and at the same or higher maximum operating speed.

3. Vibration and noise:

    a. The trucks shall minimize resonant vibrations when in operation. Surface contact between truck components, except suspension stops, shall be made through service-proven, non-metallic materials selected to impede the transmission of vibration and noise.

    b. All truck mounted equipment, including but not limited to gearboxes, motors, wiring, and brake system components, shall comply with the Effects of Shock and Vibration on Vehicle Equipment section in Section 2, Design and Performance Criteria.

4. Speeds: Trucks shall operate safely at all speeds from zero up to vehicle design speed, as specified in Section 2, Design and Performance Criteria, and produce the specified ride quality at all speeds up to the maximum operating speed specified in Section 2, over the entire range of wheel wear and vehicle loading on the SEPTA alignment.

5. Corrosion-resistant design and drainage: Trucks shall be treated with **approved** corrosion protection systems. Pockets, cavities, and partially enclosed spaces shall have provisions to prevent buildup of debris, liquids, and condensation.

11.2 Design Requirements

11.2.1 Wheelbase

Truck wheelbase: 1,780 to 1,910 mm (70 to 75 in).

11.2.2 Interchangeability

Comply with the following:

1. Powered trucks shall be interchangeable among every vehicle provided under the Contract, without modification.

2. Non-powered trucks, if provided, shall be interchangeable among every vehicle provided under the Contract, without modification.

3. All components shall be interchangeable among all trucks to the maximum extent possible. Interchangeability among trucks of a given type shall include the following at a minimum (where applicable):

    a. Wheels and axles

    b. Gear units

    c. Journal bearings

    d. Motors

    e. Brake discs

    f. Brake units

    g. Ground brushes and brush assemblies

    h. Safety bars

    i. Suspension springs

    j. Vehicle-body interface element

    k. Load-sensor assemblies

    l. Speed sensors

    m. Truck disconnect connectors

    n. Track brakes

11.2.3 Wheel Truing Machines

Wheel truing: Provide suitable adapters and fixtures to permit wheel truing on SEPTA's Hegenscheidt Type U2000-150 wheel truing machines.

11.2.4 Clearance Requirements

Comply with the following:

1. The complete truck assembly shall clear the vehicle body and vehicle-body-mounted equipment by minimum 38 mm (1.5 in).

2. For center trucks that do not swivel under the center vehicle-body section, this clearance may be reduced to 13 mm (0.5 in).

3. All truck parts, except wheels and track brakes, shall clear the plane of the top-of-rails by minimum 50 mm (2 in).

4. These clearance limits shall be met when full allowance is made for the most unfavorable combinations of the following:

    a. Wheel tread or flange wear.

    b. Static and dynamic primary and secondary spring deflection.

    c. Primary and secondary suspension failure.

    d. Static and dynamic suspension stop deflection, including possible wear of the suspension stops to the condemning limit.

    e. The full specified range and worst-case combination of horizontal and vertical curves.

    f. Other possible movements of the trucks and associated parts, including those caused by the maximum excursions of truck-mounted parts.

11.2.5 Truck Removal

Provide a design that allows for the following:

1. There shall be clear and direct access from the side or under the vehicle to all mechanical, electrical, pneumatic, hydraulic, and other connections necessary for trucking and de-trucking.

2. All such connections shall be operable with common hand tools.

11.3 Suspension System

11.3.1 General Requirements

Comply with the following:

1. Truck suspension shall consist of a primary and secondary suspension system. The vehicle body shall be supported on the secondary suspension.

2. The suspension system shall:

    a. Produce stable operation at all defined speeds.

    b. Produce specified ride quality.

   c. Retain and locate the vehicle body relative to the truck centerline, such that specified clearances and platform interfaces are achieved.

3. In the case of suspension failure, limit the lateral vehicle-body motion and maximum change in floor height over the loading range from AW0 to AW4, such that the following parameters are satisfied:

   a. Safe operating requirements.

   b. Clearance requirements.

   c. Prevention of interference between the doors and wayside loading platforms during door opening.

11.3.2 Primary Suspension

Comply with the following:

1. Primary suspension: Elastomeric elements in compression.

2. Vertical resonance frequency: Maximum 12 Hz.

3. Longitudinal spring rate:

   a. Maximum 15.76 MN/m (90,000 lb/in)

   b. Select such that the requirements of the Specifications are met

   c. Shall permit the axles to align properly (absent squealing or hunting) in curves

11.3.3 Secondary Suspension

11.3.3.1 General

Comply with the following:

1. Secondary suspension system: Coil springs or elastomeric springs, hydraulic springs, dampers, and related hardware.

2. Design: Shall keep the vehicle body aligned laterally and longitudinally with the truck centerline under all forces expected in rail service.

3. Stable operation and ride quality: Augment springs with dampers and other components as necessary to comply with the Specifications.

11.3.3.2 Load Leveling

Provide an adjustable hydraulic suspension system that keeps the vehicle floor level and maintains the door threshold height above top-of-rail to the value and tolerance specified in Section 2, Design and Performance Criteria:

1. Hydraulic cylinders: Provide minimum two per truck to serve as the secondary suspension elements in conjunction with or instead of coil springs. Vertical damping may be accomplished by the leveling cylinders, or by separate dampers.

2. Electro-hydraulic valves: Shall automatically control height of the floor to compensate for changes in passenger load and distribution.

3. Control system: Shall compensate for passenger loads on the primary and secondary suspensions:

    a. Primary suspension compensation may be by direct measurements, or by control algorithms using known primary suspension characteristics.

    b. Secondary suspension compensation shall be by direct measurement.

4. Floor level: Shall be maintained under all conditions, including sudden loss of suspension hydraulic pressure on either side of a truck.

5. Control System Design:

    a. Load leveling control may be combined with friction brake controls, if separate control hardware is used for each function.

    b. If control logic units are provided as part of load leveling, they shall comply with Section 17, Controls, Networks, and MDS.

    c. If hydraulic pressure control units are provided as part of the load leveling system, they shall comply with Section 12, Friction Brake System.

6. Level Status: Provide a signal via the vehicle network indicating that the leveling system is in a stable state and at desired height.

11.3.4 Dampers

Provide vertical and lateral dampers:

1. Type: Hydraulic.

2. Service life: Minimum 10 years.

3. Orientation: Comply with manufacturer’s recommendations, as installed on trucks, and detail in the maintenance manuals. It shall not be possible to install the damper in any manner other than as designed.

11.3.5 Suspension Stops

Provide lateral, longitudinal, and vertical suspension stops with replaceable elastomeric cushions:

1. Function: Shall not engage under normal operations, but shall limit maximum vehicle-body and truck motions under maintenance or suspension failure conditions.
2. Performance: Dimensions and developed forces shall limit motion to within clearance requirements.
3. Design: Stops shall be designed with a progressive rate to produce a low force at initial contact and a progressively higher force as the stop is compressed.
4. Vertical suspension stops: May be incorporated into vertical dampers or other suspension elements.

11.3.6 Wear Adjustment

The truck design shall allow for vertical mechanical adjustment of the secondary suspension to compensate for maximum wheel wear and wear or settlement of other truck parts without shims, unless **approved**:

1. Adjustments shall be made with standard maintenance-shop equipment.
2. Adjustments shall not impair the operation of the truck.
3. Adjustment at any level shall not cause the vehicle to exceed the specified dynamic envelope.
4. Adjustment range: 10% greater than the full range of tolerances plus wear.

11.3.7 Load Leveling and Load Compensation Sensors

Comply with the following:

1. The truck shall incorporate the load sensors and other devices necessary to meet the load compensation and load leveling requirements specified in this Section and Section 2, Design and Performance Requirements.
2. Transducers shall not be mounted to the truck frame or bolster.

11.3.8 Vehicle Body Roll Stabilization

Design the suspension of each truck to control vehicle-body roll to within the dynamic envelope and such that the ride-quality requirements of Section 2, Design and Performance Criteria, are met.

11.3.9 Truck Swiveling

Comply with the following:

1. Provide a truck assembly that will resist hunting (nosing) at all speeds up to the vehicle design speed as specified in Section 2, Design and Performance Criteria.

2. The truck assembly shall be sufficiently free to turn such that wheel treads do not exhibit double-groove-type wear patterns or flange wear below the condemning thickness (thin flange) before reaching condemnable high-flange condition.

3. Truck stability shall remain acceptable for all normal wheel wear and truck assembly wear or aging from zero to maximum design speed.

4. Truck stabilizing measures and turning stiffness, which includes articulation joint stiffness for the center truck, shall not cause abnormal wheel or rail wear.

11.4 Truck Frame and Bolster

11.4.1 General Requirements

Comply with the following:

1. Truck type: Inboard frame, to facilitate wheel tire replacement, or outboard frame, subject to design **approval**.

2. Truck frame and bolster design:

    a. Service-proven.

    b. Allow compensation for the expected maximum level of creep or settlement of the primary and secondary suspension springs.

3. Fabrication: By welding, castings, or a combination of the two.

4. Accessibility: Threaded fasteners, adjustment points, and structurally-critical locations shall be accessible for inspection and work using conventional means and tools.

11.4.2 Truck-to-Vehicle-Body Connection

Comply with the following requirements for connection between trucks and vehicle body:

1. Positive and safe mechanical connection such that the trucks can be raised with the vehicle body without disengaging any part of the suspension system.

2. Strength of the connection shall comply with truck-to-vehicle-body connection requirements of Section 3, Vehicle-Body Structure.

3. The truck-to-vehicle-body connection shall be sufficient to secure the entire truck to the vehicle body to prevent truck/vehicle-body separation during derailments, collisions, or other untoward events.

See Truck Removal section, above.

11.4.3 Tram and Axle Parallelism

Comply with the following:

1. Each truck frame assembly, when loaded with its share of AW2 weight, shall have the following parallelism as measured on the truck alone, and on the complete AW2 vehicle stationary on level tangent track:
    a. Axles: Parallel to within 2 mm (0.080 in) on each side at the journal centers.
    b. Difference between diagonally opposed bearing locations: Maximum 10 mm (0.40 in).
2. Provide truck tram marks located within 0.76 mm (0.03 in) of their true position.

11.4.4 Wheel Equalization

Comply with the following:

1. With the vehicle on level track under an AW0 load, lifting or dropping any wheel of a truck 38 mm (1.50 in) shall not change the load on any wheel of the vehicle more than 60%.
2. Raising or lowering any wheel on a truck up to 50 mm (2 in) shall not result in loss of contact between any of the other wheels and the rail.

11.5 Journal Bearings

Comply with the following:

1. Type:
    a. Grease lubricated, tapered or spherical roller bearings.
    b. NFL (No Field Lubrication) with seals designed and service-proven for use on light rail vehicles.
2. Application: There shall be no sliding surfaces involved in the method of retaining the journal bearings in their proper positions.
3. Inspection or service: None requiring disassembly before a major truck overhaul.
4. ABMA L10 rating life: Minimum 1,600,000 km (994,194 mi) at any vehicle weight up to AW4 with the shock and impact loads typical of rail vehicle service.
5. Service-proven: For use in a similar rail vehicle.
6. Bearing housings: Electrically isolated from the truck frame by the primary suspension or other means.
7. Journal bearings shall have an electrically conductive path to the journal bearing housings.

11.6 Wheels

11.6.1 Description

Comply with the following:

1. Type: Resilient wheel with a steel tire and steel center (hub).

2. Tire material: Comply with ASTM A551/A551M Class DHT.

3. Profile: See Section 2, Design and Performance Criteria and Appendix C.

4. Maintainability:

   a. Tire shall be replaceable by bolted connections, and shall not require pressing off any axle components.

   b. Resilient wheel rubber blocks shall not require change out more frequently than the wheel rims.

5. Wheel Assembly Product: SAB/Wabco V-type with noise dampeners, Bochum 84, or other **approved** design.

6. Rating: The wheel and tire assemblies shall be rated by the manufacturer for continuous operation at vehicle weights up to and including AW4.

7. Wheel Diameter and Wear: See Section 2, Design and Performance Criteria, for requirements.

11.6.2 Conductive Path to Rail

Comply with the following:

1. Function: The wheel assembly shall serve as the interface for electrically connecting the vehicle to the running rails for the following purposes:

   a. Safety ground.

   b. Return of propulsion and auxiliary current.

   c. Shunting of signal system track circuits from rail-to-rail.

2. Capacity: Sufficient to conduct specified currents via minimum three external shunts per wheel, between hub and tire. See Section 9, Electrical Equipment, for additional requirements related to return circuits, ground brushes, and safety grounding.

3. Current path: Ensure that journal bearings are isolated from shunting currents.

4. Configuration: Shunts shall not interfere with wheel truing and shall be mounted to minimize protrusion and avoid damage from wayside obstructions.

5. Shunting Resistance:

   a. Full length axle wheelset: Maximum 0.01 ohm, measured from tire tread to tire tread.

   b. Wheel tread to axle: 0.005 ohm.

   c. Measurement: See Section 15, Testing, for resistance routine tests.

11.7 Axles

Comply with the following:

1. Axles shall withstand static and dynamic stresses expected in revenue service:

   a. Standards: European standards EN 13103 for powered or non-powered outboard-bearing axles-1, BS 8535 for powered or non-powered inboard-bearing axles, or other **approved** railway-specific axle design standard.

   b. Dynamic loads for axle design:

      - Minimum in accordance with the Fatigue Design section, below.
      - Include the maximum value of stresses to which the axles are expected to be subjected in service.
      - Torque loads shall include the effects of jump frogs (flange bearing for diverging movement).
      - Include the effect of the bending loads induced by the presence of restraining rails.

   c. Allowable stress: Fatigue limits shall be per AAR Research Report No. MR-390, Table 1, unless other specific fatigue test results are available for the selected material.

2. Axle fatigue life: Meet the minimum service life requirements of Section 2, Design and Performance Criteria.

3. Material and manufacture: Per AAR M-101 Grade F (solid axles) or Grade H (hollow axles) or **approved** equal.

4. Hollow axles: If used, caps shall be provided.

5. Stub axles are permitted in 100% low-floor Streetcar only, unless **approved** otherwise.

6. For all interference fits on the axle, the pressed-on part shall overhang its respective seat on the axle.

7. Both ends of each full-length axle shall have features to reference the center of the axle.

11.8 Wheel and Axle Assembly

Comply with the following:

1. Assembly:

   a. Fit wheels, bearings, and ground brush ring to the axle by pressing or mounting.

   b. Fit tolerances and pressing forces shall be as recommended by the equipment manufacturers.

2. Records:

   a. Furnish pressure graphs of all gear coupling, disc hub, grounding ring, journal bearing, and wheel-to-axle pressings.

   b. The graphs obtained for the wheel pressing shall meet the requirements described in AAR RP-631 (AAR MSRP, Section G-II), Section 2.3, “Wheel Mounting Press Practices,” sub-section 2.3.5, and Standard RP-633, including the following figures:

      - Figure 4.19, Identification of wheel fit pressure diagram
      - Figure 4.20, Constructing and using a typical wheel mounting template
      - Figure 4.21, An example of an ideal mount
      - Figure 4.22, Example of an acceptable amount
      - Figure 4.23, Example of an acceptable mount
      - Figure 4.24, Example of a misfit where the final tonnage is not concise
      - Figure 4.25, Example of a misfit whose peak tonnage exceeds the minimum tonnage
      - Figure 4.26, Example of a misfit where tonnage does not build up to the 75% fit line
      - Figure 4.27, Example of a misfit caused by an obstruction or by excessive positive taper
      - Figure 4.28, Example of a misfit indicating an alignment problem

3. Wheel and axle assemblies shall be fully interchangeable and shall be interchangeable between powered trucks and non-powered trucks, unless **approved** otherwise.

11.9 Track Brake Support

Comply with the following:

1. The track-brake support arrangement shall maintain positive lateral alignment of the track brake with the running rail.

2. Track brake forces shall be transmitted to the truck frame as near to the top-of-rail as practical to minimize moment imposed on the track-brake unit.

3. Track brake supports that depend solely on clamping friction between the brackets and journal housings to maintain alignment are prohibited.

11.10 Safety Bars

Comply with the following:

1. Purpose: To deflect pedestrians or foreign objects and prevent them from being run over by the trucks.

2. Location: At the outboard ends of trucks:

3. Dimensions:

    a. Width: 1700 mm (66 in), or the lateral extent of truck components, whichever is greater

    b. Height: 150 mm (6 in)

4. Mounted Clearance:

    a. Maximum: 100 mm (4 in) to top of rail when all truck parts are new

    b. Minimum: 50 mm (2 in) for the worst-case combination of conditions specified in the Clearance Requirements section, above

5. Strength: Shall withstand a horizontal force of 2200 kN (500 lbf) applied at the center.

6. Maintainability: Arrange and mount for replacement with common hand tools.

11.11 Safety Hangers

Comply with the following:

1. Provide safety hangers to support motors and gearboxes if their attachments fail.

2. If motor and gearbox suspension bolts or links are longer than 150 mm (6 in), provide an **approved** safety device to prevent a failed bolt or link from dropping and creating a hazardous condition.

11.12 Design Calculations

11.12.1 Design Loads

11.12.1.1 Maximum Load Variation

Comply with the following:

1. The truck frame and all truck parts shall be capable of withstanding the maximum load variation imposed by the forces acting on the frame, in addition to the loads specified elsewhere in the Specifications.

2. Truck parts include the following:

    a. Motor

    b. Gear unit

    c. Friction and track brake equipment supports

3. The basis for determining maximum load variation shall include forces resulting from the following:

    a. Passenger load

    b. Track shocks and forces

   c. Motor torque
   d. Friction brakes
   e. Track brakes
   f. Any possible combination of these forces when operating under all possible conditions on track meeting the minimum requirements of 49 CFR 213 Class 4 track

4. Truck-to-vehicle-body attachment loads: See Section 3, Vehicle-Body Structure.

11.12.1.2 Static Strength Design Condition

The static strength design condition for the truck frame and bolster shall be based on the truck’s share of a design load weight equal to the AW4 weight minus the weight of the truck.

11.12.1.3 Vertical Load

The minimum vertical load on the truck shall be the truck's share of the design load, augmented by the weight transfer effects such as tractive effort reactions.

11.12.1.4 Longitudinal Load

The minimum longitudinal load, applied at the center of gravity of the vehicle, shall be the maximum possible instantaneous braking effort (friction and dynamic plus track brake) with AW4 loading and 50% adhesion.

11.12.1.5 Lateral Load

The minimum lateral load, applied at the center of gravity of the vehicle, shall be that developed at vehicle overturning.

11.12.1.6 Accessory Loads

Accessory loads, such as those from brake units, track brakes, and traction motors, shall represent maximum steady state conditions; for example, maximum motor torque and brake unit weight, and maximum brake unit reaction and motor weight, or the worst combination (brake blending) of both.

11.12.2 Maximum Allowable Stresses

Under the above load conditions combined, the maximum stresses at any location in the truck frame and bolster shall not exceed 50% of the yield strength of the material.

Exception: Local zones greater than the allowable will be reviewed on a case-by-case basis as long as it does not affect the overall stability of the truck. Based on this review, the Engineer will determine the acceptability of these areas.

11.12.3 Fatigue Design

Comply with the following:

1. The fatigue design of the truck frame and bolster shall be based on the above conditions with a design load equal to the AW2 weight minus the weight of the trucks. Loads on the truck shall be as follows:

    a. Vertical load: The mean vertical load shall be the truck's share of the design load; the vertical load shall vary about the mean vertical load by plus or minus 25%.

    b. Lateral load: Shall vary between 15% of the mean vertical load acting towards one side of the truck and 15% of the mean vertical load acting towards the other side of the truck.

    c. Longitudinal load: Shall vary between 15% of the mean vertical load acting towards one end of the truck and 15% of the mean vertical load acting towards the other end of the truck.

    d. The lateral and longitudinal loads shall act as if they were applied at the center of gravity of the vehicle body at AW2 with resulting vertical loading applied to the bolster or truck frame as appropriate.

    e. Accessory loads: Shall vary between plus or minus 100% of their maximum steady-state values:

        - Motor under maximum braking torque; and
        - Brake unit tractive effort reaction under full service brake application with minimum 50% adhesion; plus
        - Maximum track brake tractive effort load.

2. Loads shall be applied with the phasing to produce the worst possible stress combination. Under these conditions, stresses shall not exceed the allowable fatigue values.

11.12.4 Fatigue Allowable Stress Levels

Comply with the following:

1. Fatigue allowable stress levels for truck materials shall not exceed the following:

    a. Published endurance stress values for smooth, flat, tension-tension specimens; or

    b. Recent Contractor tests with sufficient individual tests to establish the endurance stress value for 95% survival at the 95% confidence level, as defined in ISBN: 978-0871700148, ASM Metals Handbook, 9th Edition, Volume 8: Mechanical Testing, “Fatigue and Fracture,” pages 695-720. (Note that this is a description of the statistical treatment of the fatigue data; the Contractor is responsible for finding or developing data to establish the fatigue properties.)

2. Fatigue allowable stress levels for welded connections shall not exceed the following:

    a. Requirements of AWS D1.1/D1.1M for dynamic structures; or

    b. Contractor tests of the specific connection establishing its endurance stress (load) value for 95% survival at 95% confidence level.

11.12.5 Non-U.S. Standards

Standard EN 13749, or other standards, may be permitted at the discretion of the Engineer as a basis for design conditions of the trucks, if it is shown that the truck design conditions will aim to produce a truck that meets the more severe track conditions, speeds, and truck weights in the U.S.

However, the requirements for strength of the truck-to-vehicle-body connection specified in Section 3, Vehicle-Body Structure, may not be modified or waived.

11.12.6 Stress Analysis

11.12.6.1 Scope

Comply with the following:

1. As a minimum, the stress analysis shall consist of an FEA of the global structure and a classical analysis of all connections, supplemented as necessary by manual or computerized calculations.
2. Perform a stress analysis of the end truck frame and bolster and the center truck assembly. Show the calculated stresses, allowable stresses, and margins of safety for all elements for all specified loading conditions.
3. Update the analysis as the truck design proceeds.
4. Perform a separate analysis of welds and welded connections on the finished truck frame, including welds attaching brackets, studs, and holders for truck accessories.

11.12.6.2 Service Proven Design

Comply with the following:

1. The Contractor may submit data from previous tests, historical data from operations, or stress analysis, as required above, to satisfy the corresponding portion of these requirements, only for those portions of the proposed designs that meet each of the following conditions:
    a. Based on a service-proven truck, as defined in Section 1, General Topics and Definitions.
    b. Fabricated by the same manufacturer at the same manufacturing facility.
    c. **Approved** by operating agency.
2. For a truck frame or bolster to be accepted as service proven, along with the requirements above submit the truck service history for **approval**. The submittal shall note any deviations for the SEPTA application.

11.12.6.3 Testing

The information derived from the stress analysis shall be used to determine strain gauge locations and other criteria for truck tests (see Section 15, Testing, for details).

11.13 Truck Painting

Comply with the following:

1. Paint all truck components except components specifically excluded below, in accordance with Section 16, Materials and Workmanship.

2. See Section 14, Interior and Exterior Appointments, for paint color.

3. The following truck-related items shall not be painted:

    a. Wheels

    b. Axles

    c. Elastomeric parts

    d. Grease fittings

    e. Linkages

    f. Threads used for adjustments

    g. Electrical equipment

    h. Wearing surfaces

11.14 Identification and Traceability

Provide permanent identification for each component as follows:

1. Truck frame:

    a. Serial number plate: Permanently attached and located in a conspicuous place.

    b. Figure size: Minimum 20 mm (0.8 in) high.

2. Wheels: Mark according to ASTM A551/A551M or other **approved** standards body.

3. Hubs: Mark according to AAR M107/M-208 or other **approved** standards body.

4. Axle: Mark with information required by AAR M-101, or other **approved** standards body.

5. Other truck components: Serialize as required in Section 20, Program Control and Quality Assurance.

11.15 Contract Deliverables Requirements List (CDRL)

11-1 Truck Clearance Design Package
11-2 Load Leveling Design Package
11-3 Truck-to-Vehicle-Body Connection Design Package
11-4 Journal Bearings Design Package
11-5 Axle Strength Design Package

11-6 Wheel-Axle Assembly Design Package
11-7 Truck Stress Analysis and Testing Plan
11-8 FEA Model Package
11-9 Truck Stress Analysis Report
11-10 FEA Input and Output Data
11-11 Welding Analysis Report
11-12 Service Proven Design

11.16 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Control schematics
4. Component ratings: Top level components, and ratings of other components if requested

11-1 Truck Clearance Design Package:

1. Drawings showing truck clearances under the specified worst-case conditions, with sufficient detail to demonstrate that specified clearances have been achieved.

11-2 Load Leveling Design Package:

1. Hydraulic schematic
2. Circuit diagrams of the system

11-3 Truck-to-Vehicle-Body Connection Design Package:

1. Calculations demonstrating vehicle-body-to-truck connection strength meets requirements of Section 3, Vehicle-Body Structure.
2. Instructions for de-trucking and re-trucking on flat tracks with portable jacks, including diagrams.
3. Details of lifting tools provided for de-trucking and re-trucking, if required by design.

11-4 Journal Bearings Design Package:

1. Data sheet on proposed bearing type.
2. Journal bearing L10 life calculation.
3. Sufficient data to demonstrate that the proposed bearings are service proven.
4. Description of the method used to insulate journal bearings from the truck frame.

11-5 Axle Strength Design Package:

1. Submittal shall be furnished by the axle manufacturer.

2. Proposed material specification and manufacturing requirements per AAR M-101, EN 13261, or equivalent standard.

3. Strength calculations for axles:

   a. Load diagram.
   b. Static and dynamic stress calculations for the axles that show, at a minimum, the maximum value of stresses to which the axles are expected to be subjected in service.

4. Fatigue life calculations:

   a. Prediction of axle's fatigue life using cumulative damage or other **approved** calculation method.
   b. Consideration of effect of bending loads induced by the presence of restraining rails in the axle bending fatigue stress calculations.

11-6 Wheel-Axle Assembly Design Package:

1. Axle press fitting procedures for all components pressed onto the axle.

2. Pressure graphs:

   a. Gear coupling, disc hub, grounding ring, journal bearing, and wheel-to-axle pressings.
   b. Before submitting, confirm that graphs are within the limits recommended in the AAR's Wheel and Axle Manual, as required by this Section.

11-7 Truck Stress Analysis and Testing Plan:

1. Truck Stress Analysis and Testing Plan shall be **approved** before submittal of Truck Stress Analysis Report.

2. Contractor’s chosen static and fatigue allowable values, whether published or test values.

3. Outline of the procedure to be used to analyze and test the design of the truck.

4. Table of loads to be used for static analysis and test, with load magnitudes and points of application.

5. Derivation of the static loads to be applied.

6. Table of loads to be used for fatigue analysis and test, with load magnitudes, points of application, and phasing.

7. Derivation of the fatigue loads to be applied.

8. Diagrams of load applications.

9. Table of allowable stress levels.

11-8 FEA Model Package:

1. Submit and receive **approval** of the FEA Model Package before performing the FEA and submitting the Truck Stress Analysis Report.

2. FEA input data on electronic media as **approved**.

3. Element grid, assumptions, and input data, such as loads, section properties, boundary conditions, and material properties.

4. Boundary reaction forces of the truck under its own weight.

5. Key to symbols and colors.

6. Format:

   a. Number each page, and clearly label columns of data on each page.
   b. Define terms, symbols, abbreviations, and units.

11-9 Truck Stress Analysis Report:

1. Submit after receiving **approval** for the Truck Stress Analysis and Testing Plan and the FEA Model Package.

2. Submit before truck frame static load test and fatigue endurance test (see Section 15, Testing).

3. Format:

   a. Include a Table of Contents.
   b. Number each page, and clearly label columns of data on each page using terms defined in the analysis.

4. Include the following as a minimum:

   a. Structural diagram (layout) of the truck frames and bolster showing member locations and shapes, and indicating the material and thickness of each.

      - Completely define the methods of joining, including AWS D1.1/D1.1M weld classifications for fatigue for all welds.
      - Clearly show connections between the truck, bolster, and vehicle body.

   b. Diagrams displaying external loads and supports applied to the truck frames and bolster.
   c. Summary of the results of calculations of stresses in all members:

      - Show in a separate table the locations where calculated stress levels equal or exceed 85% of the allowable stress criteria **approved** in CDRL 11-8, Truck Stress Analysis and Testing Plan, along with the design or operating conditions (loads) that cause them.
      - Calculated stresses shall be supported, where available, by the results of actual tests of trucks of identical design.

   d. Analysis of all critical connections of the truck frames and bolster major structural elements under all specified loading conditions.

e. For the truck frame and bolster members that are fatigue critical, include a tabulation of the Contractor's selection of allowable truck frame and bolster static and fatigue stresses and assumed applied fatigue stress ranges. Allowable stress levels shall be substantiated by the Contractor's test data or by citing published sources.
f. Critical welds including, as a minimum, all welds or portions of welds which, based on the results of the stress analysis and truck tests, are expected to be critical in fatigue.
g. Table showing the engineering properties of each grade and temper of each material:

- Include the material designation, yield strength, ultimate strength, elongation, Young's modulus for tension and compression, and shear elastic moduli.
- In each case, use minimum-guaranteed values from the specifications for the corresponding grade and heat treatment of the material.

5. FEA portion of the report:

a. FEA output data on electronic media as **approved**.
b. Element grid, all assumptions, and all input data, such as loads, section properties, boundary conditions and material properties.
c. Color plots showing the following:

- Deflections in all three axes separately plotted and imposed over the deflected shape
- Von Mises, or other **approved** combination stresses
- Maximum and minimum principal stresses
- Direction of maximum and minimum principal stresses
- Meshing accuracy index
- Locations of strain gauges, shown on plots of the FEA truck and bolster mesh with dimensions

11-10 FEA Input and Output Data:

1. In addition to submitting FEA input data with the FEA Model Package, submit the input files each time the files are changed, but not more often than monthly.

2. In addition to submitting FEA output data with the Truck Stress Analysis Report, submit the output files each time the files are changed.

3. Submit on electronic media as **approved**.

4. Criteria for final **approval** of the Truck Stress Analysis Report include submittal of the fully configured input data files.

5. Each revision shall be accompanied by detailed revision notes that explain each change and indicate where changes were made in the report as a result of the change.

11-11 Welding Analysis Report:

1. Fatigue classifications of each weld according to AWS D1.1/D1.1M.

2. Drawings of truck welding locations, or FEM mesh plots with the weld locations indicated, with the AWS classification indicated.

11-12 Service Proven Design:

1. For a service-proven truck, submit data from previous tests, historical data from operations, or stress analysis.

2. Include a summary stating specifically what portions of the submittal requirements are intended to be satisfied by the submitted material.

11.17 Referenced Standards

The following standards are referenced in this Section:

49 CFR 213	Track Safety Standards
AAR M-101	Axles, Carbon Steel, Heat-Treated
AAR M-107/M-208	Wheels, Carbon Steel
AAR RP-631	Recommended Wheel Shop Practices
AAR RP-633	Figures
ASTM A551/A551M	Standard Specification for Carbon Steel Tires for Railway and Rapid Transit Applications
AWS D1.1/D1.1M	Structural Welding Code – Steel
BS 8535	Railway applications - Wheelsets and bogies - Powered and non-powered axles with inboard bearings - Design method
EN 13103-1	Railway applications - Wheelsets and bogies - Design method for axles with external journals
EN 13261	Railway applications - Wheelsets and bogies - Axles - Product requirements
EN 13749	Railway Applications - Wheelsets and bogies - Method of specifying the structural requirements of bogie frames
ISBN: 978-0871700148	ASM Metals Handbook, 9th Edition, Volume 8: Mechanical Testing

END OF SECTION

Table of Contents

12.1 General

12.1.1 Scope

The friction brake system includes spring-applied, hydraulic-release disc brakes with rotors, calipers, and actuators; track brakes; sanders; electronic control units; hydraulic pressure control unit; and related components.

12.1.2 Configuration

Control: Friction brake controls may be independent, or embedded in the propulsion system.

Load-Weigh System: Equipment and controls shall be part of the friction brake system.

Load-Leveling System: Functions shall be performed by the friction brake system.

12.1.3 System Description

Comply with the following:

1. Friction braking shall be arranged as a physically and functionally independent system for each truck on the vehicle.
2. The friction disc brake system shall perform the following functions:
   a. Perform service and emergency braking in the event of dynamic brake failure;
   b. Perform emergency braking with the assistance of dynamic brakes, track brakes, and sand;
   c. Act as a parking brake system;
   d. Supplement dynamic braking on a per powered-truck basis, to provide the requested service braking efforts in all cases where dynamic braking is not providing the requested efforts.
   e. Interface and interact with the Communications Based Train Control (CBTC) system, as specified in Section 2, Design and Performance Criteria, and Section 21, Communications Based Train Control.
   f. Interface and interact with the Collision Avoidance System, as specified in Section 21, Communications Based Train Control.
   g. Indicate system status and faults to Operator (see Section 5, Operator’s Cab Controls) and log system status and fault details in MDS (see Section 17, Controls, Networks, and MDS).
3. If a non-powered truck is provided, see Section 2, Design and Performance Criteria, for allocation of dynamic and friction braking.

12.1.4 Performance Requirements

Comply with the following:

1. See Section 2, Design and Performance Requirements, for brake performance requirements, and performance related to wheel spin/slide system, load leveling, and sanding.

2. Performance shall be achievable under the worst-case combination of LVPS or battery voltage, reservoir fluid level, accumulator charge, and ambient temperatures.

3. The friction brake system shall have the thermal capacity to operate continuously with the duty cycles specified in Section 2, Design and Performance Criteria.

4. Complete disc brake release shall be achievable at all vehicle speeds down to zero, and under the worst-case combination of LVPS or battery voltage, reservoir fluid level, accumulator charge, and ambient temperatures.

12.1.5 Power Sources

All friction brake equipment shall operate from the vehicle's dc low-voltage power supply (LVPS), except as may be permitted below.

12.1.6 Audible Noise

The disc brake rotor, caliper, and pad assembly shall not emit audible squeal, chatter, or other undesirable sounds.

12.2 Components

12.2.1 Configuration

Comply with the following:

1. For through-axles, provide at least one rotor and caliper per axle.

2. Provide two track brakes for each truck.

3. Provide sanding on each end truck.

12.2.2 Rotor and Hub Assembly

Comply with the following:

1. Type: Ventilated one-piece or split-disc rotor, retained to hub by bolted connection.

2. Durability:

    a. Shall resist warping and cracking due to thermal stress resulting from the specified duty cycle.

b. Shall have service life such that replacement cycle coincides with interval for truck overhaul cycle.

3. Wear indication grooves: Provide on both edges of each rotor to indicate the minimum allowable thickness.

4. Balance: Rotor and hub assembly shall statically balance within 0.28 N-m (40 ozf-in).

12.2.3 Actuators, Calipers, and Brake Pads

Each rotor shall be equipped with a spring-applied, hydraulic-release brake actuator:

1. Each caliper shall act as a parking brake by removal of hydraulic pressure.

2. The brake actuator shall include an automatic slack adjustment feature, which shall compensate for brake pad and rotor wear as well as assure drag-free running.

3. Brake actuators shall be mounted to floating calipers designed as follows:

   a. To follow the rotor regardless of lateral rotor motion.

   b. To accommodate all other relative motions between the rotor and the caliper to maintain full brake pad engagement with the rotor, and prevent binding, accelerated wear, or damage to truck or brake components.

4. Actuators and calipers shall be interchangeable:

   a. Powered truck: Among all powered truck axles.

   b. Non-powered truck: Among all non-powered truck wheel-axle assemblies.

5. Brake pads and holders shall be designed for quick pad replacement without disassembly of the caliper unit. Brake pads shall be interchangeable among all axles of the same type.

12.2.4 Hydraulic Pressure Control Units (HPCU)

12.2.4.1 General

Provide each truck with an independent hydraulic pressure control unit (HPCU):

1. It shall include the following:

   a. Hydraulic fluid reservoir and accumulator

   b. Motor-driven pump

   c. All necessary control valves and pressure transducers

2. Function: Shall control hydraulic pressure to the brake calipers in response to commands from the brake control units.

3. Location: Adjacent to their respective trucks, in an area protected from dirt, dust, wheel splash, and unusual heating conditions, such as cooling air outlet from propulsion equipment or radiant heat from brake discs, to prevent damage.

4. Mounting: Onto the vehicle structure, via resilient mounts.

12.2.4.2 Reservoir and Accumulator

Comply with the following:

1. Hydraulic fluid reservoirs:

    a. Design to minimize the potential for contamination from particles or moisture.

    b. Provide with a breather-filter and pressure release valve.

    c. Provide with a drain plug, fluid-sight-level glass, and a self-sealing, quick-connect coupler for filling and draining that are accessible from ground level.

2. Accumulators:

    a. Provide with the means to be charged or discharged through a test port accessible from the ground.

    b. Provide with sufficient pressure levels, volumes, and pressurized fluid levels to meet the required performance and response times for brake applications and wheel-slip control specified in Section 2, Design and Performance Criteria, at all ambient conditions.

3. Provide sufficient accumulator hydraulic storage capacity to allow at least three EB applications after loss of hydraulic pump power:

    a. Assume accumulator hydraulic volume is at its normal minimum level at the time of power loss.

    b. Brake application and release shall be as follows:

        - FSB level for an AW3 vehicle weight
        - Brakes shall be applied for at least 30 seconds per application and released for 2 minutes between applications
        - Normal brake modulation shall be available

    c. The required capacity shall be available under all specified environmental conditions.

4. The reservoir and accumulator volumes shall be augmented as necessary for load leveling.

5. Provide brake controls with a means to detect the following:

    a. When the fluid level in the hydraulic fluid reservoir is below the level recommended by the friction brake supplier for continued safe operation.

   b. When any hydraulic accumulator supply volumes drop below the minimum value necessary to achieve an all-friction service brake stop at AW3. When any hydraulic accumulator supply volumes are within 5% above this value, indicate “Maintenance Required” message.

6. When a low-fluid supply-reservoir level or low accumulator-supply volume or pressure is detected the controls shall perform the following:

   a. Restrict speed.

   b. Indicate a friction brake fault for the vehicle on the Cab Console with details logged by the MDS (see Section 5, Operator’s Cab Controls, and Section 17, Controls, Networks, and MDS).

12.2.4.3 Hydraulic Pump

Comply with the following:

1. Power: Hydraulic pumps shall be powered by the dc LVPS via brushless dc motors, or via three-phase induction motors powered from auxiliary ac inverter.

2. Pump motors:

   a. Type: Totally enclosed, sealed bearings, non-ventilated, rated for wash-down applications.

   b. Mounting: Such as to prevent ingress of hydraulic fluid or fumes.

   c. Designs in which the motor pump operates continuously to maintain pressure are prohibited.

3. The hydraulic pump shall supply the pressures for the load leveling system.

4. See Section 9, Electrical Equipment, for general electrical and failure management requirements.

12.2.5 Pressure Transducers

Comply with the following:

1. Provide pressure transducers for control, feedback, testing, and the failure monitoring system. Pressure switches are not permitted, except as necessary to transmit system information to the MDS and TOD upon loss of electronic controls.

2. Transducers shall be low-drift, temperature-compensated devices that operate minimum five years without requiring calibration.

3. Transducers shall be powered from isolated power supplies and shall not interface directly with vehicle battery-level circuits.

12.2.6 Parking Brake

Comply with the following:

1. Description: The parking brake shall be inherent in the caliper design (see this Section). Parking brakes shall be held in the released state by hydraulic pressure.

2. Control:

   a. The parking brake control signal shall be configured to release the parking brakes when energized.

   b. See Section 5, Operator's Cab Controls, for automatic application of parking brakes.

3. A parking brake applied anywhere on a vehicle shall inhibit propulsion and brake release indications.

12.2.7 Disc Brake Cutout

Comply with the following:

1. Provide a means for manual release of the brakes from the side of the vehicle, or via other **approved** methods, as follows:

   a. One hydraulic cutout per truck.

   b. Individual mechanical cutout for each caliper.

2. When the service brakes are cut out, the following interlock contacts for the service brakes shall be bypassed on that truck only:

   a. Brake release

   b. Low-fluid level

   c. Low-accumulator-supply-pressure

3. Indicate a friction brake fault for the vehicle on the Cab Console with details logged by the MDS (see Section 5, Operator's Cab Controls, and Section 17, Controls, Networks, and MDS).

4. Cutting in the service brakes shall automatically reset interlock contacts to normal operation.

12.2.8 Track Brakes

Comply with the following:

1. Performance: The electromagnetic track brake system shall be effective at all speeds from vehicle design speed down to zero speed, over all conditions of curves and grades.

2. Control:

   a. Automatic: See Section 2, Design and Performance Criteria.

   b. Manual: See Section 5, Operator's Cab Controls.

c. Track brake control and logic shall be provided separate from the friction brake ECU.

d. Indicate and record activation of track brake (see Section 5, Operator’s Cab Controls, and Section 17, Controls, Networks, and MDS).

3. Cutout:

a. Provide on a per-truck basis via sealed switch located in the cab electrical locker.

b. When a track brake is cut out, provide the following:

- Local friction brake fault annunciation for that truck
- Friction brake fault indication with details logged (see Section 5, Operator's Cab Controls and Section 17, Controls, Networks, and MDS)

4. Environmental:

a. Track brakes shall be fully watertight.

b. Coils shall be enclosed in a non-magnetic, corrosion-resistant case with coil voids filled to form a hermetically-sealed unit.

5. Mounting:

a. Track brake forces shall be transmitted to the truck through bonded rubber elements.

b. Track brake mounting that enables quiet operation that does not require rubber elements may be proposed.

6. Rail Contact: Wear surfaces shall be smooth and shall not wear grooves or ridges in the rail head throughout the life of the track brake shoe.

7. Maintainability:

a. If it is necessary to remove the track brake to renew the rubber elements, they shall be applied to the track brake assembly rather than the truck.

b. Track brake shoes and the pole filler material shall be readily replaceable.

c. Shall include provision for adjustment to maintain proper clearances.

8. Clearance:

a. Track brakes shall not interfere with track, wayside, or truck components under all normal conditions and combinations of wear.

b. In the area between the railhead and 51 mm (2 in) above top of rail, the track brake shall not extend laterally beyond the wheel-tire cross section with fully worn track-brake shoes.

9. De-energized state:

a. The track brake shall be suspended above the rail by springs and shall be located laterally by resilient stops.

b. Track brake motion while suspended shall not produce audible noise under any normal operating condition.

c. Vertical clearance above top of rail, when de-energized, shall be maintained under all loading conditions.

10. Electrical:

    a. Coils shall be electrically isolated from grounds and shall be terminated in a built-in two-pin connector or other **approved** connection.

    b. The track brake shall include a freewheeling diode.

    c. Connection to vehicle wiring shall be via flexible cable with waterproof connectors at both ends.

    d. Provide a separate track brake contactor and circuit breaker for each truck.

    e. Tripped or open track brake circuit breakers shall cause annunciation of a friction brake fault, and shall be logged.

12.2.9 Electronic Control Unit (ECU)

Unless control is via the propulsion system, provide an independent friction brake ECU for each truck. Comply with specified electrical requirements and Section 17, Controls, Networks, and MDS.

12.3 Controls

12.3.1 General

Comply with the following:

1. The friction brake system shall include microprocessor-based controls (Braking Control Unit, or BCU) on a per-truck basis:

    a. Each BCU shall independently read master controller and other signals from the controlling cab and the propulsion controls. The BCU shall calculate and apply the requested brake effort.

    b. Each BCU shall connect to the vehicle data network, transmit system status, and perform fault logging.

    c. If friction brake controls are embedded in the propulsion ECU, provide similar friction brake status and fault logging within the propulsion system design.

2. Emergency braking shall be initiated directly by hard-wired signals from the Cab Console to all brake control valves, track brake contactors, and sanding controls, and shall not be processed by the BCU, except for monitoring purposes.

12.3.2 Dynamic Brake Interface

A dynamic brake signal from the propulsion system shall be used by each BCU to modulate disc brake effort in response to the dynamic braking effort on that truck, such that the requested brake effort is produced regardless of the status of dynamic braking:

1. The propulsion and friction brake suppliers shall jointly determine the characteristics of this signal.
2. If the disc brake control logic is within the propulsion system, the propulsion control ECU shall calculate the required disc braking effort so as to produce the requested level of effort within specified tolerances. See Section 10, Propulsion System and Control.

12.3.3 Load Compensation

Comply with the following:

1. The friction brake system shall use the signals from the load measuring system on each truck to adjust disc brake efforts according to passenger load, on a per truck basis. See Sections 2, Design and Performance Criteria, and 11, Truck Assemblies.
2. If the load compensation signal is not within the allowable range, the system shall default to the value of the nearest accurately reporting truck and notify the Operator through the MDS (see Section 17, Controls, Networks, and MDS).
3. The friction brake system shall include the equipment and controls for the load measuring system, and may send processed load signals to the propulsion system.
4. Failure of any portion of the load compensation system shall result in not less than AW0 signal.

12.3.4 Wheel Spin/Slide Detection and Correction

Provide a wheel spin/slide detection and correction system as specified in Section 2, Design and Performance Criteria, as an integral part of the friction brake control system:

1. Coordinate system with propulsion and friction brake spin control and slide control functions.
2. Analog or digital wheel spin/slide control signals shall cause the following:
    a. Disc brake system shall reduce disc braking effort in response to wheel spin/slides.
    b. Shall proportionately reduce disc braking levels on the affected truck such that disc-brake effort is reduced to a level appropriate for slide correction.
3. The disc brake control logic shall process the wheel spin/slide signal, as required, to accommodate any disc brake system non-linearities.
4. Indicate and log a spin/slide fault for the vehicle (see Section 5, Operator’s Cab Controls, and Section 17, Controls, Networks, and MDS).

5. Interface with the CBTC system specified in Section 21, Communications Based Train Control, to notify CBTC when wheel slide is detected and wheel slide mitigation is active to permit adjustment to CBTC braking calculations and control.

6. System shall function when vehicle is being towed (rescue operation) and battery power is available.

12.3.5 CBTC Braking Enforcement

The braking system shall be capable of receiving and acting upon vital braking enforcement commands from the CBTC system as specified in Section 21, Communications Based Train Control. The braking system shall coordinate with the propulsion system to enable blended brake and enforce power cut as per Section 10, Propulsion System and Control.

12.3.6 Collision Avoidance System Braking Enforcement

The braking system shall be capable of receiving and acting upon vital braking enforcement commands from the Collision Avoidance system as specified in Section 21, Communications Based Train Control. The braking system shall coordinate with the propulsion system to enable blended brake and enforce power cut as per Section 10, Propulsion System and Control.

12.3.7 Snow Brake

Comply with the following:

1. Provide the snow brake function through the brake control unit to retain a constant brake cylinder pressure.

2. Provide a Snow Brake switch in the cab electrical locker that when energized illuminates an indicator on the Cab Console.

3. The snow brake shall provide automatic periodic release to allow for slack adjustment while snow brake is in use.

    a. Design the method and frequency of automatic periodic release to ensure full braking effort is maintained based on continuous use of the snow brake function.

    b. Submit details of the snow brake function for **approval**.

4. Indicate and record activation of snow brake (see Section 5, Operator’s Cab Controls, and Section 17, Controls, Networks, and MDS).

12.4 Load Leveling System

12.4.1 General

Load leveling system functions shall be performed by the friction brake system.

12.4.2 Source Power

The leveling system for each truck shall be powered from the same independent hydraulic source as the truck's disc brake system, unless otherwise **approved**.

12.4.3 Control

Comply with the following:

1. The system shall maintain floor heights on each side of the vehicle within specified tolerance and passenger loadings.
2. Leveling pressure control valves shall be separate from the brake pressure control valves, but may be mounted together.
3. Height control logic and other electrical components shall be separate from the BCU logic, but may share the electrical enclosure and power supplies.
4. Controls and height sensing elements shall be sufficient to maintain the specified accuracy.
5. System response time shall be sufficient to achieve the defined floor height before doors fully open, and to maintain floor height during passenger embarking and debarking.
6. Failure of the leveling system shall not reduce the safety and functionality of the braking system, and the leveling system shall be included in the friction brake system's diagnostic system.
7. Indicate failure of leveling system on Cab Console with details logged by the MDS (see Section 5, Operator's Cab Controls, and Section 17, Controls, Networks, and MDS).

12.5 Disc Brake - Propulsion System Interlock

Comply with the following:

1. Interlock the disc brake system with the propulsion system such that propulsion is removed if any disc brake remains applied on any truck for more than a designated time period after the application of propulsion.
2. Initial setting: 7 seconds.
3. Time value: Adjustable in software, and optimized during vehicle testing.
4. Indicate a friction brake fault for the vehicle on the Cab Console with details logged by the MDS (see Section 5, Operator's Cab Controls, and Section 17, Controls, Networks, and MDS).

12.6 Sanding System

Comply with the following:

1. Sander type:

    a. Pneumatic with integral compressors. Separate compressors may be proposed. Compressor shall be oil-less and maintenance-free except for input filter cleaning.

    b. Gravity-fed systems may be proposed, if specified flow rates can be ensured under all conditions.

2. Application points: Sand shall be applied to the wheel/rail contact point at the front of each leading wheel of powered trucks for both directions of operation.

3. Control:

    a. Automatic application:

        - System shall apply sand in response to brake applications and spin/slide activities, in accordance with the braking requirements in Section 2, Design and Performance Criteria.
        - During maximum and emergency braking, sand shall be applied to the wheel/rail contact point at the front of each leading wheel of powered trucks for both directions of operation.
        - During a wheel spin or slide, sand shall be applied only in front of the leading axle of the vehicle that detected the spin or slide.
        - Sanding shall be interlocked with the no-motion detection circuitry and disabled below the no motion detection point.

    b. Manual application:

        - Possible only if a vehicle direction is selected but shall not be interlocked with the no-motion detection point.
        - During manual application, sand shall be applied to the wheel/rail contact point at the front of each leading wheel of powered trucks for both directions of operation.
        - See Section 5, Operator's Cab Controls, for Operator manual control of sanding (audible alarm sounded in active cab, and logged on vehicle event recorder).
        - Include provision to permit manual testing of the system operation.

4. Electrical:

    a. Power source: DC LVPS for all sander functions, including heaters and compressors.

    b. Circuits: Feed sanders for each truck from a separate circuit breaker. Provide a sealed switch, located in the cab electrical locker, to allow per-truck cut-out function.

    c. Friction brake fault: Annunciate system fault, tripped or open breaker on TOD, and log on MDS (see Section 5, Operator's Cab Controls, and Section 17, Controls, Networks, and MDS).

5. Sand boxes:

    a. Quantity: Four

    b. Location:

        - Inside vehicle, under seats, suitable to feed sand to each specified point of application.
        - The seats shall be hinged and equipped with a spring latch to secure the seat in the down position. For keying requirement, see Section 14, Interior and Exterior Appointments.
        - Fill location: Exterior with spring loaded, sealed, weathertight cover. Cover shall include key lock.

    c. Material: Stainless steel or aluminum.

    d. Capacity: Minimum 20 liters (5.3 gallons) per box.

    e. Configuration: Slope sandbox bottom towards the floor outlet with the slope angle greater than the angle of repose of the sand, such that all sand in the box can be dispensed.

    f. Environmental protection:

        - Seal to prevent moisture and debris ingress
        - Heat to keep sand dry from condensation

6. Filling:

    a. Sight gauge: Provide one for each sandbox, visible from inside vehicle, to indicate sand level.

    b. Filling portal: Arrange sandbox to permit easy filling from inside or outside vehicle.

7. Output:

    a. Through piping or hose selected and arranged to permit the free flow of sand to the nozzles under all conditions of environment and truck motions.

    b. Tees, elbows, or other restrictive fittings are prohibited.

8. Sanding nozzles:

    a. Fastened to the truck frame.

    b. Shaped and located to deposit sand directly in front of and as close as possible to the specified wheel/rail contact points.

    c. Designed to reject water caused by wheel splash.

    d. Shall not clog under any specified environmental conditions.

    e. Shall be heated.

    f. Shall be accessible for inspection and replacement with the use of standard hand tools and without the need to disassemble any other truck or vehicle-body component.

9. Flow rate: Initially set at approximately 0.45 kg/min (1 lb/min), with flow rate and activation time automatically adjusted per vehicle speed. System shall include software provision to allow flow rate to be adjusted by shop personnel by minimum +/- 25% of the nominal setting.

12.7 Contract Deliverables Requirements List (CDRL)

12-1 Friction Brake System Design Package
12-2 Track Brake Design Package
12-3 Friction Brake Control Design Package
12-4 Thermal Capacity Design Package
12-5 Sanding System Design Package
12-6 Friction Brake Redistribution Scheme

12.8 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, installation, and other drawings if requested
2. Functional description including mechanical, electrical, and network interfaces
3. Control (electric and hydraulic) schematics
4. Component ratings: Top level components, and ratings of other components if requested

12-1 Friction Brake System Design Package:

1. Description of friction brake system
2. Details of parking brakes
3. Description of EB application
4. Hydraulic fluid specifications
5. Details of truck cut-out and mechanical brake release
6. Outline drawings and mounting of major components
7. Hydraulic system schematics

12-2 Track Brake Design Package:

1. Data sheets on track brake components with sufficient detail to demonstrate that specified requirements have been satisfied
2. Outline drawings of overall system

3. Illustrations demonstrating how to replace track brake shoes, pole filler material, and bonded rubber elements

4. Illustrations demonstrating how to make adjustments to maintain proper clearances

12-3 Friction Brake Control Design Package:

1. Hardware and software functional description, including all interfaces and their interdependencies

2. If friction brake control is accomplished by propulsion equipment, demonstrate that sufficient information from the friction brake supplier is furnished on the following:

   a. Friction brake physical and electrical characteristics
   b. Transfer functions
   c. Network communications
   d. All other aspects necessary to achieve specified performance

3. Interfaces with propulsion system

4. Hardware design description

5. Wheel spin/slide detection and correction including slide control safety supervision algorithm specified in Section 2, Design and Performance Criteria

6. Snow brake function description

12-4 Thermal Capacity Design Package:

1. Coordinate with propulsion run time simulations; verify that all operating and other assumptions are the same.

2. Input assumptions.

3. Ambient and initial equipment temperature assumptions.

4. Verification of the thermal capacity of the braking equipment under the selected abnormal duty cycle.

5. Level of braking assumed on extended downgrades in degraded modes.

6. Speed/time/brake disc temperature/distance plots of the vehicle on the Project alignment.

7. Temperature predictions (or actual test results) for brake discs.

12-5 Sanding System Design Package:

1. Narrative description of the system detailing options selected to deliver sand.

2. Data sheets on system components

3. Outline drawings of overall system

12-6 Friction Brake Redistribution Scheme:

1. For EB and slide controlled braking

2. During dynamic brake failure (if applicable)

12.9 Referenced Standards

There are no standards referenced in this Section.

END OF SECTION

Table of Contents

Table of Tables

13.1 General

13.1.1 Scope

The onboard communication system includes: the public address system (PA), intercom system including passenger emergency intercom (PEI) and cab-to-cab intercom, automatic vehicle locator (AVL) system, automatic passenger information system (APIS), warning devices, voice radio, closed circuit television (CCTV), including video surveillance, the event recorder, automatic passenger counting (APC), fare collection; traffic light priority, public world wide web, and train-to-wayside communication (TWC) system.

13.1.2 General Requirements

Comply with the following:

1. Power source: Communication equipment shall be powered from the dc low-voltage power supply (LVPS) (see Section 9, Electrical Equipment), and shall be rated for continuous duty in the specified environment, as installed.

2. Grounding: Communications equipment circuits shall comply with the safety grounding and return circuit requirements of Section 9.

3. Network: The communications system, and equipment, shall be Ethernet-based. All audio and visual messages, displays, and controls shall be networked to all vehicles in a train.

4. Design requirements: The communication controls shall comply with the design requirements of Section 2, Design and Performance Criteria, and incorporate a Local Diagnostic and Test System (LDTS) that interfaces with the Central Diagnostic System (CDS) and portable test units (PTU), as specified in Section 17, Controls, Networks, and MDS, and Section 19, System Support.

13.1.3 Communication System Integration with MDS

The APIS, Communications, and MDS hardware, wiring, and functions may be integrated to the maximum extent possible. For information on the MDS, see Section 17.

13.1.4 Audio Communications Functional Description

The communications system shall be configured to allow the following audio communications:

1. From the Operator to passengers inside and outside the vehicle.

2. Between cabs in a vehicle, and the cabs of other vehicles in the train.

3. Between passengers inside the vehicle and the Operator.

4. From the APIS to passengers inside or outside the vehicle or both via pre-recorded announcement sequences and visual displays.

5. From the door system to passengers inside and outside the vehicle, if door warnings are generated by one of the vehicle communication systems.

13.2 Public Address (PA) System

13.2.1 General

Comply with the following:

1. The PA system shall permit the Operator to make audio announcements to passengers inside or outside the vehicle, and to enable audio announcements from the APIS.

2. Operator-initiated PA messages shall override APIS and door system messages.

3. Both live and pre-recorded audible announcements shall be reproduced verbatim in visual format. See the Automatic Passenger Information System (APIS) section, below.

4. Related sections:

    a. See Section 5, Operator's Cab Controls, for a functional description.

    b. See Section 6, Passenger Doors, for door functions performed by the PA system, if door warnings are generated by the PA system.

13.2.2 Performance

Comply with the following:

1. Messages shall be intelligible and acoustically pleasing under all operating conditions.

2. Frequency response: Measured from signal origin to output signal at the speaker, shall be 150 Hz to 10 kHz, +/- 1 dB at all power levels.

3. Total harmonic distortion: For all circuits, without compression circuits, shall not exceed 1% at 1 kHz, full output.

4. Output volume and audio quality: Same from each speaker.

5. Speech peaks: Limited to approximately 5 dB above the average input level.

6. Intelligibility:

    a. When tested according to IEC 60268-16, the PA system shall have measured speech transmission index (STI) from the input of the microphone, or audio messages from the APIS, to the output of the speakers as follows:

        - No measurements below 0.5 STI at 80 dB background ambient noise

    b. Use test signal recommended by manufacturer of STI measuring instrument.

13.2.3 Amplifiers

Comply with the following:

1. Provide network-connected amplifiers driving one or more speakers, with sufficient power to drive all connected speakers at maximum levels, simultaneously, without distortion.

2. The frequency response of power amplifiers below 100 Hz shall fall off at a rate of maximum 6 dB per octave.

13.2.4 Automatic Volume Control

The PA system interior and exterior output levels shall be automatically adjusted in accordance with ambient noise levels before each announcement, regardless of origin:

1. Range of automatic adjustment: Minimum 10 dB.
2. Maximum output level (interior): Minimum 15 dB above typical worst-case ambient noise levels when the vehicle is moving at maximum operating speed.
3. Maximum output level (exterior): Minimum 15 dB above typical worst-case ambient noise levels when the vehicle is stationary at a station selected by the Engineer.

13.2.5 Cab Microphone

Provide a microphone in each cab, usable for PA, cab-to-cab, and PEI modes:

1. Type: Boom-style, gooseneck, or console-mounted, noise-cancelling, dynamic.
2. Durability: Rugged, weatherproof construction, designed and constructed for transportation applications, IK09 impact rated, and vandal-resistant.
3. Location: Shall permit a seated Operator of the specified size range to speak into the microphone without leaving the normal operating position or losing sight of traffic in front of the vehicle. See Section 14, Interior and Exterior Appointments, Size Range of Operators section.
4. Wiring connector: Quick-disconnect type.
5. Microphone preamplifier: Shall include a compression circuit that maintains output regulation of + 1/- 0.5 dB, no load to full load, measured at the speaker terminals.

13.2.6 Interior Speakers

Interior speakers shall meet or exceed the following criteria:

1. Provide two redundant circuits to ensure that announcements can still be heard if an amplifier or speaker fails for one circuit. Each circuit shall also be equipped with fault detection, which shall be shared with MDS as part of Section 17, Controls, Networks, and MDS, for display to Operator and maintenance staff.
2. Select speaker dispersion and other characteristics to produce sound levels within 3 dB, and intelligible audio, at all seating locations, under all vehicle operating conditions.
3. Provide speakers with a continuous power rating of minimum 5 W.
4. Design system to eliminate feedback from any audio input source.
5. Provide audio fidelity specified in this Section at all power levels.

6. Mount speakers in the ceiling, or other **approved** locations.

7. Grilles shall be flush mounted, finished to match the panel, perforated, removable for access to the speaker, and held in place with tamper-proof screws as specified in Section 16, Materials and Workmanship.

8. Provide a volume adjustment control for the Operator's cab PA speaker that can be adjusted by the Operator.

9. Speakers shall be rated minimum IP54 for dust and moisture ingress.

13.2.7 Exterior Speakers

Exterior speakers shall meet or exceed the following criteria:

1. Provide a minimum of four external speakers per vehicle, two per side.

2. Speakers shall be impervious to environmental conditions specified in Section 2, Design and Performance Criteria.

3. Provide speakers with a continuous power rating of minimum 15 W.

4. Mounting of speakers and routing of speaker wires shall be IP66 waterproof.

5. Speaker locations shall not violate the vehicle's dynamic outline.

6. Speakers shall be immune to the chemicals and detergents normally used during vehicle washing, shall not interfere with nor damage mechanical vehicle wash brushes, and shall be designed to withstand forces generated by these brushes.

13.2.8 PA Passenger Alert Tone

Comply with the following:

1. Preceding any public audio announcement, including automatic announcements, a local tone annunciator shall be energized to alert passengers that an announcement is forthcoming.

2. The tone volume shall be 3 dB above the normal speech level.

3. The annunciator shall possess a pleasant, chime-like quality, and be **approved**.

13.2.9 Assistive Listening System

13.2.9.1 General

Provide an Audio Frequency Induction Loop assistive listening system that provides coverage to the entire vehicle for all audible announcements. Alternate technology that offers the same level of accessibility may be used with Engineers **approval**. For signage requirements, see Section 14, Interior and Exterior Appointments. Supply ten (10) sets of all diagnostic test equipment necessary to test and maintain the assistive listening system.

13.2.9.2 Functional Description

Proposed technology shall have the capability of coupling directly to hearing aids and cochlear implants, or other personal hearing devices, without an additional receiver.

13.2.9.3 Audio-Frequency Induction-Loop System (AFILS)

Where the required assistive listening system is provided by an AFILS, comply with IEC 60118-4.

13.3 Intercom System

13.3.1 General

The intercom system shall allow communication between passengers and the Operator, and between vehicle cabs.

13.3.2 Passenger Emergency Intercom (PEI)

13.3.2.1 General

The passenger emergency intercom shall permit passengers to communicate with the Operator.

13.3.2.2 PEI Station Quantity and Location

Comply with the following:

1. Quantity: Provide a minimum of four PEI units.
2. Location: Provide one in each of the two dedicated mobility aid parking areas and one near each end of the vehicle, or as directed by the Engineer during design review.

13.3.2.3 PEI Stations

Comply with the following:

1. Description: Flat-faced, panel-mounted enclosure with microphone, loudspeaker, large pushbutton switch, indicating light (which may be part of the pushbutton switch), and any necessary auxiliary components to make the system function.
2. Enclosure:
    a. Material: Stainless steel.
    b. Rating: IP65 splash-proof, IK10 impact rated, and vandal-resistant.
    c. Front panel: Perforated in front of microphone and loudspeaker with holes as small as possible to enable adequate performance while reducing opportunities for vandalism.
3. Microphone: Omni-directional, with external filters to reduce background noise.

4. Loudspeaker:

    a. Materials: Same requirements asinterior PA speakers.

5. Pushbutton: Arranged to prevent unintended nuisance application during crowded conditions in passenger area.

6. Electrical connections: PoE. Other connection methodologies (e.g., concealed multi-pin connectors) are subject to **approval**.

7. Signage:

    a. Text: English, Spanish, and Braille.

    b. Identification: EMERGENCY INTERCOM adjacent to unit.

    c. Instructions: Provide signage with **approved** language on unit's operation adjacent to unit.

    d. Unit location: Provide signage identifying the vehicle and PEI unit location adjacent to unit.

    e. Determent: IT IS A VIOLATION OF FEDERAL REGULATIONS FOR AN UNAUTHORIZED PERSON TO USE THE PASSENGER EMERGENCY INTERCOM WHEN NO EMERGENCY EXISTS adjacent to unit.

    f. Signage regulations:

        - Comply with 36 CFR 1191 Appendix D, Section 703, Signs.
        - Provide tactile symbols and characters that comply with 36 CFR 1191 Appendix D, Section 703.2, Raised Characters, in accordance with 36 CFR 1191 Appendix D, Section 407.4.9, Emergency Communication.

8. Installation: Flush mount each unit at a height of 1220 mm (48 in) above the floor. The installation shall comply with 36 CFR 1191 Appendix D, Section 308, Reach Ranges.

13.3.2.4 Functional Description

The system shall function as follows:

1. Pressing the call-request button at a PEI station:

    a. Causes the call request to form a party line with the the PEI control system.

    b. Indicates acknowledgement of the call request to the passenger with a light on the PEI station and an audible notification.

2. When the call request comes to the Operator's cab from the PEI station:

    a. The Operator is hailed via a tone and indicator lamp at the active Cab Console.

    b. The Operator acknowledges each call by pressing an acknowledge button, which sets up a communication channel between the active cab and the PEI station.

    c. The Operator may speak to passengers when the microphone switch is pressed, and the passengers may speak to the Operator when the switch is not pressed.

   d. Audio from the passengers is heard in the active cab speaker. Audio from the Operator is heard by the passengers via the speaker in the active PEI stations. Audio from each active PEI station shall be heard at other active PEI stations when the Operator's microphone switch is not pressed.

3. When all conversations are finished:

   a. The Operator terminates the call by pressing a button on the Cab Console and the active PEI stations return to an inactive state.

4. If the Operator activates other audio functions on the Cab Console:

   a. PEI activities are placed on hold and the queue maintained.

   b. The PEI indicator lamp on the Cab Console shall remain illuminated.

   c. The Operator shall return to the PEI session by pressing a button on the Cab Console.

13.3.3 Cab-to-Cab Intercom

Provide a cab-to-cab intercom to allow communication between cabs within the vehicle, and between cabs of other vehicles in a train:

1. Function: Similar to the PEI (may use the same equipment).

2. Call initiation: From any cab, with or without an active console.

3. Call annunciation: In every cab, by means of a one-time call chime and an indicating light.

4. Call acknowledgment: In any cab.

5. Indicating lights: Shall stay on until the call is completed.

6. Connection between vehicles: Make provisions for connection during towing operations. A separate cable that attaches at either cab end through a weatherproof connector will be acceptable.

13.4 Computer Aided Dispatch and Automatic Vehicle Location System (CAD/AVL)

The vehicle shall be equipped with a real-time dispatch and vehicle location management and display system. The supplier shall be identical to the supplier of CAD/AVL for SEPTA's CARD (Computer-Aided Radio Dispatch) system which will be identified by SEPTA during design review.

1. The system shall provide vehicle location, updated at regular intervals, using GPS along with dead-reckoning to permit vehicle location detection when operating in tunnel areas using one or more dedicated speed sensors.

2. The system shall forward time synchronization signals to other network attached equipment within the communications network as per Section 17, Controls, Networks, and MDS. Critical equipment within the Propulsion Control Network shall not receive a time synchronization signal from the AVL system, although the source shall still be GPS.

3. The GPS antenna shall mount on the roof, or other location, optimized for satellite access. Coordinate the antenna location with other vehicle antennas to avoid interference and meet the requirements of the Radio Interference Study to be performed as per Section 2, Design and Performance Criteria.

4. The system shall be equipped with a Mobile Data Terminal (MDT) located within reach of the Operator within each cab as per Section 5, Operator's Cab Controls, that shall permit the Operator to perform some of the following, with other requirements to be discussed during design review:

   a. Operator login including methods using a smart card

   b. Audio and visual indications to the operator if not logged in during departure

   c. Route assignment (Block number)

   d. Functions supporting the CARD system to be discussed during design review

5. The system shall interface with a carbuilder supplied silent alarm button discretely located in each cab within reach of the Operator to trigger the following:

   a. Forward silent alarm signal to dispatchers at SEPTA's Operations Control Center via interface to the radio system

   b. Trigger display of appropriate signage on exterior vehicle signs with content as **approved** by SEPTA.

   c. Send discrete I/O contact closure to CCTV system to flag CCTV footage for active silent alarm.

   d. Enable the CAD/AVL workstation at SEPTA's wayside to trigger covert monitoring (i.e., a one-way voice call from the vehicle).

   e. The alarm shall conform to the practices recommended in APTA RT-VIM-RP-025-15, Section 2.14, Cab covert alarm.

6. The system shall interface with the voice radio system in a manner consistent with SEPTA's existing bus fleets.

7. The system shall interface with the APIS system as required including providing location data and operator login.

8. The system shall use two-way data transmissions necessary to support the CAD/AVL system.

9. A data interface between the CAD/AVL system and the Fare Collection equipment (see Section 14, Interior and Exterior Appointments) on the vehicle shall be installed.

13.5 Automatic Passenger Information System (APIS)

13.5.1 General

The vehicle shall include equipment for automated broadcast of pre-recorded audible and visual announcements of transit system information as well as destination information to passengers on the wayside via integration with the AVL system:

1. The APIS components shall be fully integrated into a network-connected system as per Section 17, Controls, Networks, and MDS, with a controller common to all.
2. Type: Clever Devices IVN-R or **approved** equal.
3. The Engineer will coordinate with the Contractor to produce the initial data set of messages; station names and physical locations, announcement sign text/images, and other information necessary to commence revenue service.
4. The system shall be responsible for control of prerecorded PA announcements onboard the vehicle, including location-triggered announcements.
5. The system shall be responsible for control of preprogrammed signage to all digital signs onboard the vehicle, including location-triggered signage.
6. See Section 6, Passenger Doors, for door functions performed by the APIS, if door warnings are generated by the APIS.

13.5.2 Functional Description

The APIS system shall function as follows:

1. After the Operator selects the route, announcements are triggered automatically without Operator assistance or may be triggered manually by the Operator:
    a. Automatically: By vehicle position, determined by a combination of GPS coordinates, distance measurement by wheel revolution count, accelerometers, gyroscopes, and door openings.
    b. Manually: Via the APIS Control Panel in each cab.
2. Destination signs shall automatically be set.
3. Audio announcements shall be broadcast over the PA system, and corresponding verbatim visual announcements displayed on the interior information signs.
4. The message database structure shall include instructions to direct audio to the interior, exterior, or both speaker sets.

13.5.3 Passenger Information

The system shall include as a minimum the following passenger information:

1. Station arrival announcement: Station identification may include station name, exit locations, and bus or train transfer information.
2. Station departure announcement: Broadcast the following information:
    a. Next station with associated ADA compatibility information
    b. Vehicle destination/route information
    c. Which doors will be opening at the next station
3. End of Line
4. Train going out of service announcements
5. Public Service Announcements

13.5.4 Operator Controls

Provide an APIS Control Panel (AVL MDT) in each cab:

1. Location: Integrated into the Cab Console in a less-frequently used area. If **approved**, may be integrated into the CAD/AVL MDT as described in Section 13.4.
2. Functionality: It shall allow the following:
    a. Initiating the system
    b. Entering temporary information such as vehicle ID and Operator ID
    c. Entering route ID (block number)
    d. Selecting specific messages
    e. Altering the normal message sequence, such as skipping stations
    f. Display of system status and other relevant information
3. Interface Device:
    a. It shall include a keypad or similar with function specific keys. Entering commands via codes is prohibited.
4. Display: LED back-lit LCD display or **approved** alternate showing the following information:
    a. System status
    b. Entered information
    c. System diagnostic and fault data

d. Presently announced messages

e. Similar information, as directed by the Engineer

13.5.5 System Initiation

Comply with the following:

1. Master Controller (MC) key switch On: The system shall initiate itself to the last route ID, or to a default setting if the last active ID is not present.

2. MC key switch Off: The route ID shall be stored.

3. Allow login from CAD/AVL MDT.

For a functional description of Operator initiation of APIS announcements, see Section 5, Operator’s Cab Controls.

13.5.6 Message Format, Uploading, and Recording

Comply with the following:

1. Audio format: Messages shall be encoded and stored in a common, publicly available, digital format such as WAV, MP3.

2. Audio sample rates and compression levels: Chosen for excellent human voice and good music fidelity at the speaker.

3. Message, station, and route data: Uploadable via Ethernet, USB, or as **approved** to meet cybersecurity requirements in Section 17, Controls, Networks, and MDS.

4. Recorded audio messages: The initial set shall be created in a professional recording studio, using a trained female English speaker, or **approved** text-to-speech algorithms.

13.5.7 Data Storage and User Programming

Comply with the following:

1. The APIS shall use a non-proprietary, publicly available, database structure to store all data.

2. Each audio, text message shall be stored with, or linked to, related information identifying the message type, destination device addresses, distance-on-route for automatic message triggering, and similar parameters.

3. Updating, creating, deleting, uploading, and downloading APIS information shall be database structured, and contained within one program; recording of audio messages can be performed using different software.

13.5.8 System Capacity

Comply with the following:

1. For storage, assume for audio messages at least 30 seconds per message and for text messages 100 characters each.

2. Message capacity shall depend only on available memory; there shall be no inherent limitation built into the control software or algorithms.

3. The system shall have enough capacity to store the following:

    a. 50 routes, with a minimum of 100 stations for each route;

    b. 10 audio and 10 text messages per station;

    c. Minimum 50 special messages, audio and text.

13.5.9 Performance

APIS audio performance shall be the same as for the PA.

13.5.10 Recording and Programming Equipment

Furnish to SEPTA a complete set of equipment for recording and modifying the visual and audible messages and routes:

1. The system shall be composed of standard commercial off-the-shelf (COTS) equipment.

2. This equipment shall include everything required to reprogram the onboard systems with new information, such as messages, routes, and stations.

13.5.11 Information and Destination Signs

13.5.11.1 General

Provide an electronic information and destination sign system on each vehicle:

1. Regulations and Standards: Comply with 49 CFR 38, Subpart D (ADA requirements).

2. Quantity: Each vehicle shall have a minimum of four interior information and four exterior destination signs.

3. Environmental protection: Protect signs from the following:

    a. Environmental contamination

    b. Ingress, as appropriate for the operating environment

4. Maintainability: LCD panels shall be user-replaceable, and of a common design and format available from multiple sources in the U.S.

5. Network interfaces: Comply with Section 17, Controls, Networks, and MDS.

13.5.11.2 Information Signs

Comply with the following:

1. Type: Industrial-grade LED-backlit color TFT LCD display assembly, for interior viewing.
2. Integrated components:
    a. Power supplies and dc-dc converters (if required)
    b. Display drivers
    c. Announcement controller interface
    d. Media server:
        - Commercially available, supporting media content file extensions including but not limited to MP3, MP4, WAV, JPEG, JPG, PNG, MPEG.
        - Cybersecurity requirements for media server are specified in Section 17, Controls, Networks, and MDS.
3. Types of visual information to be displayed:
    a. Alignment map: Actively show current position, direction of travel, the next four stops along the alignment, and information on the current route status, including anticipated stop arrival times. Map color as selected by SEPTA.
    b. Next station: Show name and on which side doors will open.
    c. Station specific: Information such as adjacent destinations and safety messages.
4. Infotainment: Advertisements, news, weather, real-time information, and other content within a fully customized playlist administered by SEPTA. Graphics: Videos, pictures, photographs, or artwork representing each station or landmarks near the station.
5. Display size: Minimum 530 mm (21 in) diagonal.
6. Resolution: Minimum 1920 x 1080; wide screen formats acceptable.
7. Refresh rate: High, with no detectable flicker.
8. Characters for announcements:
    a. Minimum height: 75 mm (3 in).
    b. Width-to-height ratio: Between 3:5 and 1:1.
    c. Stroke-width-to-height ratio: Between 1:5 and 1:10.
    d. Quantity: Enough characters to fill the width of the message portion of the display, scrolling horizontally as necessary
9. Viewing angle: Minimum 160 degrees horizontal and vertical.

10. Brightness: Minimum 500 cd/m².
11. Temperature operating range:
    a. At least -23 to 65 degrees C (-10 to 149 degrees F).
    b. No damage to the display assembly in the temperature range as specified in Section 2, Design and Performance Criteria.
12. Protective cover: Vandal resistant, clear polycarbonate shield over the display.
13. Ethernet connected to announcement controller.
14. Power source: Vehicle dc LVPS via local power supplies.
15. Cooling: Configure the enclosure, installation, and LCD panel to use conditioned interior air without forced air cooling.
16. Location:
    a. Low-floor section: Mount two as a pair, back to back, hung from the ceiling near the center, oriented transversely.
    b. High-floor sections: Integrate into fixed portion of cab partition.
    c. Situate to permit any passenger in the vehicle to have a view of at least one sign.
    d. Coordinate placement with CCTV cameras such that signs do not obscure CCTV field of view.

13.5.11.3 Destination Signs

Comply with the following:

1. Type: Single-line, dot-matrix LED or back-lit LCD, capable of scrolling a message, for exterior viewing.
2. Message:
    a. Length: Minimum 15 alphanumeric characters.
    b. Color: Yellow or amber on black.
3. Characters:
    a. Width-to-height ratio between 3:5 and 1:1.
    b. Stroke-width-to-height ratio between 1:5 and 1:10
4. Display: Destination or route information.
5. Cab front display:
    a. Location: Above each cab windshield.
    b. Character height: Minimum 150 mm (6 in).

   c. Visible at a minimum distance of 46 m (150 ft) in bright sunlight.
   d. Coordinate with upper lighting fixture design to ensure glare-free visibility under all conditions.

6. Side display:
   a. Location: On each side near a side entry door; alternate locations may be proposed.
   b. Character height: Minimum 110 mm (4.3 in).

13.6 Warning Devices

13.6.1 General

Comply with the following:

1. Provide a horn and bell on each end of the vehicle for alerting automobiles and pedestrians.
2. Horns and bells shall comply with appropriate federal, state, and local regulations.

13.6.2 Automobile Warning Device (Horn)

Comply with the following:

1. Horn: Multiple-tone electronic air horn.
2. Audible output: Minimum 95 dBA at 30 m (100 ft) in front of vehicle, adjustable by maintenance personnel.
3. Location: Mount underneath cab floor.
4. Existing vehicles: The sound shall be similar to existing vehicles.
5. Operation:
   a. Sound shall continue as long as switch is activated.
   b. When activated, only horn facing the direction of motion shall sound.
   c. While horn is activated, high and low beam headlights facing the direction of motion rapidly cycle and hazard flashers are activated.

13.6.3 Pedestrian Warning Device (Bell)

Comply with the following:

1. Bell: Electronic, traditional-sounding trolley bell with repeating sound of approximately two strikes per second. Sound may be produced by amplified, digitally-sampled audio data using heavy-duty weatherproof speakers on each end of the vehicle.
2. Existing vehicles: The sound and repetition rate shall be similar to existing vehicles, or as **approved** during design review.

3. Audible output: Provide two volume settings, low and high, adjustable by maintenance personnel.

    a. High: 75-80 dBA measured 30 m (100 ft) from front of vehicle.

    b. Low: 50-55 dBA measured 30 m (100 ft) from front of vehicle.

4. Operation:

    a. Sound shall continue as long as switch is activated.

    b. When activated, only the bell at the end where it was activated shall sound.

13.7 Voice Radio

13.7.1 General

Provide radio equipment in each Operator's cab, including wiring and power as per SEPTA radio specifications:

1. Provide Motorola Model MCS 2000 radio, required mounting accessories, and associate wiring harnesses.

2. Provide backup VoIP functionality without manual transfer utilizing the WCN Data Radio. See Section 17, Controls, Networks, and MDS for WCN details.

3. See Section 5, Operator's Cab Controls, for location information.

4. The Contractor shall be responsible for installing and testing the radio.

5. The radio shall be separately shipped to SEPTA, where SEPTA will program and provision the radio to permit it to connect to SEPTA's radio network, prior to installation on vehicle.

6. The Contractor shall be responsible for testing and integrating radio system interfaces with the Automatic Vehicle Location system.

7. Radio frequencies, for reference, to be used by SEPTA:

Frequency 1	UHF at 488-512 MHZ
Frequency 2	700 MHz if indicated by SEPTA during design review

13.7.2 Radio Antenna

Install antenna and cable per radio antenna manufacturer's requirements:

1. Antenna Location: On the roof of the vehicle near each radio transceiver.
2. Antenna Installation:
    a. Shall not exceed the dynamic envelope of the vehicle.
    b. Shall not interfere with nor damage mechanical vehicle washer brushes and shall be designed to withstand forces generated by these brushes.
    c. Waterproof without the use of sealers or caulk.
    d. Shall allow replacement of the antenna without cutting or damaging the antenna cabling.
3. Provide cable between the antenna and the radio head, as recommended by the radio manufacturer.
    a. Keep cable length as short as possible.
    b. Keep cable away from high-power cables that could cause interference to the low-power antenna signal.
4. Antenna lightning surge arrester: Provide in cabling between antenna and radio in a location that is accessible for maintenance.

13.7.3 Radio Power Supply

For each set of radio equipment, provide an industrial grade dc-to-dc power converter (if required) that complies with Section 9, Electrical Equipment, and includes the following:

1. Characteristics complying with radio manufacturer's requirements.
2. The following features:
    a. Transformer-isolation
    b. Input voltage transient suppression rated for minimum 150 J
    c. Output overvoltage protection
    d. Short circuit protection
    e. Current limiting
3. Output voltage: As recommended by the radio manufacturer.
4. Line and load regulation: 1% or less over the full range of the dc LVPS input voltage and from no-load to rated output.

5. Rating:

    a. For continuous output current 25% greater than the maximum load current drawn by the radio transceiver and all other relevant loads.

    b. The converter may be used to power other cab equipment that requires the same dc voltage as the radio, in which case the power rating of the converter shall be selected accordingly.

6. Power the radio equipment via dedicated dc circuit breaker. If the supplied radio is a fixed, non-portable unit, power the radio power supply through a circuit breaker directly connected to the battery, upstream of the battery circuit breaker.

13.8 Closed Circuit Television (CCTV)

13.8.1 General

Comply with the following:

1. Provide each vehicle with a Gatekeeper Ethernet TCP/IP-based closed-circuit television (CCTV) system consisting of Gatekeeper color cameras, display screens, Gatekeeper NVR with Crash-Hardened Memory Module, and other ancillary equipment, as required.

2. The vehicle network, CCTV controller, and NVR shall have sufficient bandwidth to record all cameras at the highest defined camera resolutions and frame rates without loss of data.

3. The vehicle CCTV system shall be standalone from other onboard networks, but shall be capable of forwarding CCTV system fault conditions to the MDS through discrete I/O, as well as receiving trigger inputs from other systems through discrete I/O.

13.8.2 Cameras

Comply with the following:

1. Calculate and demonstrate the camera views and image quality as per APTA IT-CCTV-RP-001-11:

TABLE 13-1, CAMERA VIEWS		
Passenger Interior		
View	**Quality**	**Frame Rate**
Each door	Identify	15 fps
All other passenger areas	Monitor	15 fps
Fare machine	Identify	15 fps
Exterior		
View	**Quality**	**Frame Rate**
Exterior side-view	Monitor	30 fps
Each door	Monitor	15 fps
Cab		
View	**Quality**	**Frame Rate**
Windshield forward facing	Identify	30 fps
Operator	Monitor	15 fps

2. Design: Choose lenses and enclosures as appropriate for each application.

3. Camera characteristics:

   a. As required to meet visibility requirements. Only fixed cameras supplied by Gatekeeper are permitted and panoramic fisheye cameras are prohibited.

   b. Power source: Power over Ethernet (PoE) IEEE 802.3af or 802.3at from network switch.

   c. Minimum dynamic range: 120 dB.

   d. Low-light sensitivity: 0.2 lux or better (when measured at 1/30 second, F 1.4, IRE 30). Demonstrate that the camera does not “white out” when operating at night.

   e. Colors: Minimum 16-bit color depth.

   f. Compression: Cameras shall support both H.264 and H.265 codecs, but H.265 shall be utilized for all recording and live viewing.

   g. Frame rate: Minimum 30 fps, with lower rates available.

   h. Control: Frame rate and bandwidth for each camera shall be remotely controllable using the CCTV Controller.

   i. Camera cybersecurity requirements shall be per Section 17, Controls, Networks, and MDS, even though cameras are standalone from other on-vehicle networks.

   j. Interior cameras shall support audio recording, but audio recording shall be enabled only after **approval** by Engineer as part of design review. SEPTA shall also be able to enable audio recording at a later date by an approved method. Space shall be reserved as part of requirements in Section 14 for signage to notify passengers that audio recording is active.

13.8.3 Camera Enclosures

Comply with the following:

1. Interior Camera Enclosures: Vandal-resistant, IK10 impact rated, industrial grade.
2. Exterior Camera Enclosures:
    a. Waterproof IP68.
    b. Heating Elements: Provide for defrosting and de-fogging, with control such that clear view for exterior camera is available within 10 minutes of activation of any cab and is maintained while any cab is active.
    c. Non-Snagging: Design shall prevent snagging of carwash brushes or debris.
    d. View Port: Tempered glass.
    e. Removable: Without affecting camera adjustments.

13.8.4 Interior/Exterior Surveillance CCTV

Provide each vehicle with the following surveillance cameras:

1. Interior Surveillance:
    a. Enough on the vehicle interior to ensure complete coverage of all passenger areas, including all door openings looking out to the platform.
    b. Active when either cab is active, with an adjustable timer after both cabs go inactive.
2. Exterior Surveillance:
    a. Front-facing camera: Provide in each cab to give a 180-degree wide-angle front view, covering the area in front of the vehicle. Provide two cab-forward cameras in each cab if deemed necessary by the Engineer to furnish the specified view.
3. Operator Surveillance:
    a. Camera in each cab, oriented to record audio, show all console controls, and view Operator's activities, including Operator's use of console controls.

13.8.5 Interior View CCTV Display Screen

Provide each vehicle with the following interior view CCTV display in each vehicle cab:

1. Type: LCD TFT, LED backlit
2. Reflection/glare mitigation: Provide a shroud to prevent washout during bright conditions, and a filter or coating, if necessary; filter or coating shall not reduce clarity or brightness
3. Minimum screen size: 254 mm (10 in)
4. Environmental requirements as per Section 2, Design and Performance Criteria

5. The following video feeds shall be automatically displayed on the interior view CCTV display:
    a. When vehicle is in motion: Overview of vehicle interior
    b. When vehicle is stopped:
        - By default: Overview of vehicle interior
        - Automatic cycling with interior view triggered by the doors open signal: Show views of open doors from inside vehicle
        - When passenger intercom is active: View of passenger intercom area
        - All alternate views interlocked with zero speed.
        - All other alternate views manually selected via interacting with the CCTV Screen

13.8.6 Exterior Side View CCTV

13.8.6.1 Functional Description

In place of side-view mirrors for the Operator, CCTV shall enable the Operator to supervise the loading and unloading of passengers at vehicle doorways, and to verify that the doors on the vehicle are clear of passengers.

If a camera fails, the system shall indicate a failure to the Operator and automatically switch to the camera on the opposite end of the vehicle with a view of the same side of the vehicle.

13.8.6.2 Exterior Side-View Cameras

As required to provide the exterior views specified in Table 13-1.

13.8.6.3 Exterior Side-View Display Screens

Provide color display screens, two in each cab, mounted in such a way as to minimally obscure Operator sight lines, connected to the camera(s) for the matching side:

1. Type: LCD TFT, LED backlit
2. Reflection/glare mitigation: Provide a shroud to prevent washout during bright conditions, and a filter or coating, if necessary; filter or coating shall not reduce clarity or brightness
3. Orientation: Vertical
4. Size: Minimum 200 mm (8 in), diagonally
5. Resolution and Aspect Ratio: Match the display screen’s camera
6. Controls: Provide for user-adjustable contrast and brightness
7. Operating Environment: Ensure that display functions in all environments, including an enclosed unconditioned cab in worst-case ambient conditions.
8. Location: Each side of the cab as specified in Section 5, Operator’s Cab Controls

9. Maintainability: The LCD panel shall be user-replaceable, and of a common design and format available from multiple sources in the US.

10. Exterior view video feeds shall be automatically displayed on the exterior side-view display screens according to Table 13-1, Camera Views:

    a. When doors are closed, screens shall display exterior side-view by default.

    b. When doors are open, screens shall display doors.

11. Video feeds shall be manually selectable by Operator when vehicle is stopped:

    a. Doors

    b. Length of vehicle

13.8.7 Workstation Software

Comply with the following:

1. Provide CCTV Workstation software for installation on personal computers with current Windows OS:

    a. Using a network port on the CCTV controller, the software shall permit uploading operating parameters (such as sampling rates), viewing all or selected cameras in real time, downloading and viewing of video data from the NVR, verification of authenticity, image and video enhancement, and similar processes.

    b. The software shall be web-browser based, and compatible with common Internet web browsers, such as Google Chrome, Microsoft Edge, Safari, or Mozilla Firefox.

    c. The software shall enable access to recorded video data that has been removed from the vehicle and is contained in a storage device removed from the vehicle, or has been uploaded to SEPTA's server.

    d. The workstation software shall include provision to connect to SEPTA's server, navigate to stored data by vehicle number and date range, and display on the workstation.

2. Provide network-connected equipment that will accept the storage device as a simple plug-in and allow access to the data.

13.8.8 Network Video Recorder (NVR) and CCTV Controller

13.8.8.1 General

Provide a Gatekeeper NVR or multiple Gatekeeper NVR's with Crash Hardened Memory Module (DOT **approved**) in each vehicle as appropriate:

1. Camera quantity supported: Sufficient for the quantity of cameras to be recorded in each vehicle, plus two spares.

2. Capacity: Sufficient to record all cameras in use at one time.

3. Authentication: The recording method shall include a process to detect any alteration of the data after recording.

13.8.8.2 Recording

Provide for recording the cameras described above as follows:

1. Interior surveillance cameras
2. Exterior surveillance cameras end cabs only
3. Operator surveillance camera (active cab only)

13.8.8.3 Vehicle ID, Date, and Time

The NVR shall automatically include the vehicle ID and a date/time stamp on all images:

1. Vehicle ID: Entered by the user into non-volatile memory via the CCTV controller.
2. Camera ID: Provide a unique ID for each camera, such as an IP address, that is consistent in each vehicle and consistent with network requirements in Section 17, Controls, Networks, and MDS.
3. Date and time: Maintained by an internal clock, synchronized across the network though the network master clock, as specified in Section 17, at agreed intervals.

13.8.8.4 High-Rate Recording Triggered by External Events

Comply with the following:

1. Triggering events (via discrete inputs into CCTV system or internal to CCTV system):
    a. Distress signal over the radio, if provided and available for monitoring
    b. EB application
    c. Passenger emergency intercom activity
    d. Manual (emergency) door release
    e. Accelerometer input
    f. Silent Alarm button activation (see Computer Aided Dispatch/Automatic Vehicle Location System (CAD/AVL) section, above)
2. Event Flag: Continue for 15 minutes after an event trigger.
3. Storage: Provide protected area that prevents video recording from being overwritten or erased.

13.8.8.5 Storage Capacity

Comply with the following:

1. Storage capacity: Minimum 30 days of surveillance video, computed using a minimum 20 hours per day, maximum camera resolution and bandwidth, 15 fps, and specified compression.

2. Recording durations: User selectable, from one day to full capacity.

3. Capacity status: Used/unused capacity of the NVR shall be viewable by maintenance personnel and the Operator on the Interior View CCTV Display Screen, via maintenance menu. Provide a warning on the Interior View CCTV Display Screen when capacity is near full.

4. Full capacity: When reached, new data shall over-write oldest data.

13.8.8.6 NVR Data Storage

Provide the NVR with hot-swappable non-volatile memory storage:

1. Type: Solid State Drive (SSD) storage medium, if necessary storage capacity is available with commercial drives, and the Contractor can ensure a minimum 5-year life at the specified recording rates, including wear-leveling of flash memory.

    a. Furnish confirmation of predicted lifespan from the SSD manufacturer.

    b. Calculations shall account for reduction of drive capacity as flash memory wears out.

2. Security: The memory storage device shall be secured via a keyed lock, or other **approved** mechanically secure methods.

3. Playback: Provide appropriate adapter hardware and software for the memory device, including a standard Ethernet interface, for playback on a standard laptop or desktop computer while maintaining CCTV chain-of-custody.

13.8.9 CCTV Workstations

See Section 19, System Support, for CCTV Maintenance workstation requirements.

CCTV Remote Viewing workstations will be existing SEPTA workstations interfacing with SEPTA’s wayside Video Management System.

13.8.10 Remote Live Viewing

Comply with the following:

1. The CCTV system shall permit remote live viewing of CCTV cameras from designated facilities and workstations within SEPTA IT infrastructure via the Wayside Communication Network (WCN) infrastructure specified in Section 17, Controls, Networks, and MDS.

2. The system shall stream remote live footage at reduced resolution and frame rate such as to not overwhelm available network bandwidth. To support this functionality, cameras shall be configured with two streaming profiles: one for recording and a second profile for live viewing.

3. This functionality shall comply with cybersecurity requirements specified in Section 17.

4. Remote live viewing shall occur from existing SEPTA Gatekeeper Video Management System workstations via a federated architecture.

13.8.11 Wireless Video Offload

The CCTV system shall automatically offload flagged video footage to wayside video storage when within range of WCN coverage specified in Section 17, Controls, Networks, and MDS.

1. The WCN network shall be configured to ensure that offload of video footage is balanced to not overwhelm network. Daily CCTV footage shall be offloaded within 15 minutes of entering WCN coverage area.

2. Wireless video offload shall interface with SEPTA's existing wayside Gatekeeper CCTV infrastructure.

13.9 Event Recorder

13.9.1 General

Provide each vehicle with a fully electronic data recorder system, independent of the monitoring and diagnostic system specified in Section 17, Controls, Networks, and MDS:

1. The primary purpose of this recorder is to furnish documentation in support of accident investigations.

2. It shall be a tamper-proof, self-contained design capable of withstanding high shock. SEPTA's operating environment is described in Section 2, Design and Performance Criteria.

3. The event recorder shall be based on a family of service proven designs, with permitted updates to account for cybersecurity requirements in Section 17.

4. Unless explicitly stated otherwise, the event recorder shall comply with the requirements of IEEE Std 1482.1.

13.9.2 Functional Requirements

Comply with the following:

1. Signal sampling and recording rates shall comply with IEEE Std 1482.1.

2. The event recorder shall record at least the following information:

    a. Speed sensor input

    b. Other speed input (GPS)

    c. No motion

    d. MC Reverser position

    e. Direction of actual movement

    f. Time including date, UTC format

    g. System/subsystem time(s) originated by systems generating required signals

h. Odometer

i. Active cab (make-up relay)

j. Vehicle number (from vehicle wiring)

k. Traction and Braking Command Inputs:

- MC handle position
- Discrete motor/brake trainlines
- MC emergency command
- All other emergency or automatic brake application commands initiated by the cab (e.g. dead-man, mushroom button
- Alerter penalty brake activation signal
- Emergency trainline
- Track brake activation signal

l. Traction and Braking Feedback Inputs:

- Wheel spin/slide activation (lead axle)
- Wheel spin/slide activation (other trucks)
- Sanding
- Traction motor torque signal (one truck)
- Brake apply summary trainline
- Brake cylinder pressure

m. Doors and Door Control:

- All doors closed and locked trainline
- Door close command (left/right)
- Door open command (left/right)
- Door enable command (left/right)

n. Lights and Warnings:

- Headlights on
- Auxiliary lights
- Horn activated
- Bell/gong activated

o. CBTC:

- CBTC speed limit

- CBTC measured speed
- CBTC Bypass
- CBTC EB activation signal
- CBTC penalty brake activation signal
- CBTC propulsion and braking commands
- CBTC overspeed detected
- CBTC wheel diameter
- CBTC movement authority limit
- Brake assurance accelerometer
- CBTC cab alarm activated
- CBTC control signals
- CBTC measured train location
- CBTC fault conditions

p. Collision Avoidance System

- Collision Avoidance System Bypass status
- Collision Avoidance System penalty brake activation signal

q. Traffic Light Priority

- Traffic Light Priority Bypass status

3. Provide minimum six spare digital channels.
4. Provide minimum two spare analog channels.
5. The event recorder time base shall be independent of other vehicle systems.
6. Event recorder functional status and failures shall be reported to the MDS specified in Section 17, Controls, Networks, and MDS.

13.9.3 Data Storage and Retrieval

The recorder shall be able to store a minimum of seven days of data, including signals from the spare channels, in non-volatile memory:

1. This memory shall not require battery backup for data retention and shall remain intact for a period at least one year after removal from the vehicle.
2. Provide the following data retrieval capabilities:

   a. Event data memory module removal

   b. Data retrieval via a USB and Ethernet port using a laptop computer as per Section 17, Controls, Networks, and MDS, and Section 19, System Support

3. Downloaded data shall be capable of being evaluated on an office computer. It shall not be possible to erase the data via the USB and Ethernet port on the recorder.

4. Provide all necessary cabling and software to transfer, evaluate, display, and print the data in tabular and graphic form.

13.9.4 Construction Requirements

The event recorder shall be constructed to comply with the crashworthiness requirements of IEEE Std 1482.1.

13.9.5 Installation Requirements

Comply with the following:

1. Locate the event recorder in the vehicle interior in an electrical locker that requires a key for access (see Key Assignment Table in Section 14, Interior and Exterior Appointments).

2. The installation shall be such that the event recorder is tamper resistant and waterproof; however, installation shall be such that the USB or Ethernet port is readily accessible once the recorder is installed.

3. Provide a terminal board with locations for all event recorder signals, including spares. Connections to the event recorder inputs shall be made at this terminal board.

13.10 Automatic Passenger Counting (APC)

13.10.1 General

Provide an Infodev automatic passenger counting (APC) system for each vehicle comparable to those provided on other SEPTA vehicles.

The system shall count the passengers that enter and exit the vehicle at each station and record the passenger count, location, time, and vehicle number in an onboard database for remote processing at a later time.

13.10.2 System Requirements

Comply with the following general requirements:

1. Memory: Sufficient to hold 45 days of data, assuming 20 round trips per day.

2. Software:

   a. Operating software: Provide what is necessary for the vehicle and wayside.

   b. PTU software: Provide software to maintain the system and download data and software necessary to analyze the data in SEPTA’s offices.

c. Licenses: Provide what is necessary for SEPTA to use the software for the design life of the vehicles.

13.10.3 APC Accuracy

The accumulated count of alighting passengers shall be within 2% for each 1,000 consecutive boarding and alighting passengers, and the accumulated count of boarding passengers shall be within 2% for each 1,000 consecutive boarding and alighting passengers.

Use the following formula for generating accurate passenger accumulated count data:

$$e_{rel} = \frac{|P_a - P_m|}{P_m} \times 100\% \leq 2\%$$

Where:

P_a = *automatic counted passenger (each separate for in and out)*

P_m = *manual counted passenger (each separate for in and out)*

Sample size is minimum 1000 passengers ($P_m > 1000$)

13.10.4 APC Doorway Equipment

Each doorway of the vehicle shall be equipped with multiple sensors and associated logic unit to sense passengers entering and exiting the vehicle.

1. The combination of sensors and logic shall properly detect and indicate the correct passenger count regardless of whether single or multiple persons are simultaneously entering or exiting a doorway, or any simultaneous or overlapping combination of entering and exiting persons.
2. The APC doorway equipment shall function accurately regardless of the size of the passenger, from small child to large adult and shall not interfere with operation of the doors.
3. Direct connections shall be used to communicate between APC sensors and the APC doorway logic unit.
4. Communication between the APC doorway logic units and the central logic unit shall be by a network that conforms to the requirements of Section 17, Controls, Networks, and MDS.

13.10.5 APC Logic Unit

Provide an Infodev APC Logic Unit to collect, process, and store the data from the APC doorway equipment:

1. It shall determine the position of the vehicle by a combination of the following:
   a. Starting location information from the APIS
   b. Distance traveled information from the propulsion system, or other **approved** source
   c. No-motion as indicated by the vehicle no-motion logic

   d. Door open status signals from the door control system

2. Logic shall process the door and location data and store it in non-volatile memory with sufficient capacity to comply with the specified memory capacity, above.

3. The APC Logic Unit shall contain logic to detect system faults and receive fault data from the APC doorway equipment.

   a. A fault log shall be maintained in the APC Logic Unit.

   b. In addition to functioning with the PTU to permit manipulation and display of this data, the system shall communicate with the MDS to transmit the fault log and permit manipulation and display of the passenger count data via the MDS specified in Section 17, Controls, Networks, and MDS.

13.10.6 APC Data Downloading

Comply with the following:

1. The data shall be available for downloading via PTU and for automatic downloading via wireless communication from the vehicle to the wayside via the WCN as per Section 17, Controls, Networks, and MDS.

2. Provide the equipment with the appropriate interfaces and software to use the vehicle wireless communications equipment to automatically transfer APC data to the wayside when the vehicle is in the Shop and Yard via the WCN specified in Section 17.

3. See also information on remote data management in the MDS section of Section 17.

4. Offloaded APC data shall be in a format compatible with SEPTA’s existing Infodev APC system.

5. Server requirements for the wayside server collecting APC data are specified in Section 17.

13.11 Fare Collection

Install fare collection equipment as specified in Section 14, Interior and Exterior Appointments, and provide fare collection network equipment to support them, as specified below.

1. To support installation of fare equipment, provide the following:

   a. Space for fare collection network switch and data radio in secure location where power is available.

   b. Provision for mounting tap-on tap-off fare card readers on both left and right side of each door.

   c. Provision for power and network cabling between identified fare card network equipment location and each fare card reader location.

   d. Provision for mounting of dedicated fare collection rooftop data radio antenna and antenna cabling.

e. Provision for the mounting and power for on-vehicle fare machines with the following characteristics:

- Dimensions: Provided during Design Review
- Power Consumption: Provided during Design Review
- Quantity per vehicle: Two
- Mounting Hardware: (Floor and/or wall) Provided during Design Review by New Payments Technology Group

2. Fare collection interior appointments shall be as specified in Section 14.

13.12 Traffic Light Priority

SEPTA may furnish a traffic light priority emitter for the roof of each cab. For each vehicle, perform the following:

1. Install SEPTA-furnished emitters, if requested by SEPTA before the end of design review.
2. Furnish for mounting brackets for emitters and install if SEPTA requests the installation of SEPTA-furnished emitters.
3. Furnish, install, program, and connect wiring, consisting of power and an interlock with active cab.
4. Furnish Traffic Light Priority Bypass switch in each cab as specified in Section 5, Operator's Cab Controls.
5. SEPTA will provide projected radio frequencies to be used for Traffic Light Priority if SEPTA requests the installation of SEPTA-furnished emitters.
   a. Coordinate radio frequencies for traffic light priority, if provided, as part of Radio Interference Study to be performed as part of requirements for Section 2, Design and Performance Criteria.

13.13 Onboard Public Wi-Fi

Provide the following infrastructure to support the installation of on-vehicle Public Wi-Fi equipment at a later date:

1. Space for surface mount on vehicle backhaul data radio and Public Wi-Fi controller within secure cabinet: 400 mm x 300 mm (15.7 x 11.8 in), with 200 mm (8 in) depth for accommodating equipment depth and cable routing.

13.14 Train-to-Wayside Communication (TWC)(Vetag) System

13.14.1 General

Provide the vehicle-borne portion of the TWC system in accordance with requirements specified in this Section. Provide vehicle TWC equipment completely compatible with the wayside equipment.

Each vehicle set of TWC equipment to be provided will consist of at least the following:

1. Two Operator TWC control modules, installed in the cab console (one per end), in **approved** locations as per Section 5, Operator’s Cab Controls.

2. Two transponder assemblies (one per end).

3. One or two TWC logic units.

13.14.2 System Description

Provide each end of the vehicle with vehicle-borne components of the TWC system to transmit digital information from the vehicle to the wayside or wayside to vehicle, at certain points along the route.

1. Fixed wayside loop antennas placed in the trackway send out an interrogation signal several times a second.

2. When a vehicle passes over the loop antenna and an activated vehicle-borne TWC transponder receives the interrogation signal it shall transmit a message to the wayside in the form of high-speed serial digital data to permit activation of wayside track switches.

3. Provide vehicle-borne equipment compatible with SEPTA's existing and new wayside systems

    a. Type: Vetag

    b. Frequencies: Wayside and vehicle-borne TWC signals will be in the 90 kHz to 100 kHz range. These frequencies shall be taken into account for the Radio Interference Study to per performed as part of requirements in Section 2, Design and Performance Criteria.

13.14.3 Functional Requirements

Comply with the following:

1. Furnish and install vehicle TWC equipment such that there is accurate, secure transmission of a data message to/from wayside loop antennas.

2. Transponders shall transmit when properly located over the loop and polled by the wayside interrogator.

3. The format of the data message to be transmitted shall be a function of vehicle status. The vehicle shall be configured to furnish the TWC system with inputs representing active cab status and end-of-train status.

4. The TWC system shall transmit the following information from the vehicle to the wayside:

    a. Switch Call (Left or Right)

After Contract Award:

1. Additional TWC transmission requirements will be covered during system design.

2. The exact assignment of bits, including start/stop bit will be furnished to the Contractor by the Engineer after Contract award.

13.14.4 Vehicle-Borne Equipment

13.14.4.1 General

Comply with the following:

1. Equipment shall be identical in all cabs.

2. Provide interconnection hardware and cables to mount and connect transponders and TWC control modules.

3. Provide power to the TWC system from the dc LVPS with the voltage range and conditions specified in Section 9, Electrical Equipment.

13.14.4.2 Operator TWC Control Module and Associated Wiring

Comply with the following:

1. The TWC control module shall consist of the following:

    a. A unit of four pushbutton switches; these shall be backlighted when the transponder for the active cab is over a wayside loop and is being interrogated.

    b. A unit of four thumbwheel switches, each with ten positions.

2. Inputs to the TWC control module:

    a. Battery positive, through a dedicated circuit breaker

    b. Negative Return

3. Installation: All inputs shall be brought to a terminal board mounted under the console in an appropriate location near the TWC control module, and connected to the TWC control module via a multi-conductor cable and quick-disconnect connector.

4. TWC status: Show on the TOD, as specified in Section 5, Operator’s Cab Controls.

13.14.4.3 Transponder

Mount each transponder under the vehicle as follows:

1. Mounting Bracket:
    a. Fabricate bracket to mount the transponder to the vehicle body
    b. Material: Follow manufacturer's requirements for electromagnetic properties.
    c. Finish: Paint the bracket as under-vehicle equipment.
2. Location and Orientation:
    a. Location and orientation shall conform to the TWC manufacturer's installation guidelines, including proximity to ferrous materials, and coordinate with SEPTA's wayside equipment and other vehicle equipment.
    b. Do not mount to truck frame unless specifically permitted by manufacturer.
3. Cable Connection:
    a. Provide a multi-conductor cable and connectors suitable for exposure in an under-vehicle environment.
    b. Attach one end of the cable to the vehicle via a connector at a bulkhead or junction box.
    c. Attach the other end of the cable to the transponder by methods appropriate for the transponder design.

13.14.4.4 TWC Logic Unit

Comply with the following:

1. Provide dc power to each TWC logic unit via dedicated circuit breakers.
2. Install logic units in equipment lockers/racks with other vehicle control units.

13.15 Contract Deliverables Requirements List (CDRL)

Assistive Listening System Design Package
Public Address Design Package
Intercom Design Package
Automatic Passenger Information System Design Package
Warning Devices Design Package
Radio Design Package
CCTV Design Package
Vehicle Position Design Package
Wi-Fi Router Design Package
Event Recorder Design Package
Automatic Passenger Counting Design Package
Automatic Vehicle Locator Design Package

Traffic Light Priority Design Package
Onboard Wi-Fi Design Package
TWC Design Package

13.16 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Each design package shall include the following, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested
2. Functional description
3. Electrical specifications
4. Control schematics
5. Circuit schematics
6. Electrical schematics
7. Component ratings: Top level components, and ratings of other components if requested
8. Vehicle integration drawings
9. Mechanical specifications
10. Mechanical assembly drawings with weights, dimensions, and parts lists
11. Software functional description: Include top level control parameters and values
12. Assembly and Installation drawings.

Public Address Design Package

Assistive Listening System Design Package:

Design details of the hearing loop driver and hearing loop.

Methods used to adequately address crosstalk and signal bleed.

Methods used to compensate for the effects of metal within the carbody structure.

Identification of the expected background magnetic noise in the loop coverage area based on similar vehicles in service in similar environments, and its effect on the audio quality of the completed loop system.

Diagnostic test equipment to be supplied.

Intercom Design Package

Automatic Passenger Information System Design Package:

Instructions for updating, creating, deleting, uploading, and downloading APIS information.

Audio encoding, recording and playback processes.

Samples of audio messages.

Destination and information signs:

Locations
Display details, including the following information:

Type
Size
Resolution
Ambient conditions
Operating voltage
Protective cover
Isolating power supply

Warning Devices Design Package:

Manufacturer's literature.

Sounds (electronic audio files)

Radio Design Package

CCTV Design Package:

Camera manufacturer's data.

Camera locations, coverage study, capacity, control software, and arrangement.

Display screen manufacturer's data, including the following:

Type
Size
Resolution
Ambient conditions
Operating voltage
Protective cover
Isolating power supply
For touch screen, response to cold hands/fingers, gloves

Details of CCTV network controller

NVR manufacturer's data.

NVR authentication process to detect any alteration of the data after recording.

CCTV wireless remote viewing and offload architecture.

Workstation software

Automatic Vehicle Location Package:

Details on accuracy, error detection and other parameters as required

Interface with voice radio system

Interface with APIS system,

Silent alarm functionality

Event Recorder Design Package:

Event recorder manufacturer's data

Details of interfaces and installation.

List of signals to be made available at the specified terminal board.

Automatic Passenger Counting Design Package:

Measured accuracy data for similar rail applications with double-wide doors.

Accuracy type test report, as specified in Section 15, Testing, as part of Communications Equipment Type Test.

Automatic Vehicle Locator Design Package:

Traffic Light Priority Design Package

Onboard Public Wi-Fi Design Package

TWC Design Package

13.17 Referenced Standards

The following standards are referenced in this Section:

36 CFR 1191 Appendix D	Technical
49 CFR 38, Subpart D	Light Rail Vehicles and Systems
APTA IT-CCTV-RP-001-11	Selection of Cameras, Digital Recording Systems, Digital High-Speed Networks and Trainlines for Use in Transit-Related CCTV Systems
APTA RT-VIM-RP-025-15	Recommended Practice for Operator Protection Features for Rail Transit Vehicles

IEC 60118-4	Electroacoustics - Hearing aids - Part 4: Induction-loop systems for hearing aid purposes - System performance requirements
IEC 60268-16	Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index
IEEE Std 1482.1	Standard for Rail Transit Vehicle Event Recorders

END OF SECTION

Table of Contents

Table of Tables

14.1 Scope

This Section includes interior finishing, including liners, insulation, floor covering, seats, and windows; layout and design of the Operator's cab and Cab Console; exterior finishing; and other such features and appurtenances.

14.2 Interior Finishing

14.2.1 Materials

Provide only the following types of materials:

1. High-durability, low-maintenance, as specified in this Section and in Section 16, Materials and Workmanship, or as **approved**.
2. Conforming to flammability, smoke emission, and toxicity requirements of Section 16.
3. Color shall extend all the way through materials except FRP and melamine (where FRP and melamine are specified).
4. Materials shall be designed to be vandal resistant.

14.2.2 Design and Workmanship

Comply with the following:

1. The vehicle interior shall be free of sharp corners or edges.
2. Surfaces shall be free from tooling marks, gaps, distortions, and other visible defects.
3. Surfaces shall be rigid and supported to prevent sagging, drumming, and vibration.
4. Gaps between fittings that are not absolutely rigid shall be wide enough to prevent injury when one or more fitting moves or provide rigid spacers to prevent the gap from closing.
5. Like components shall be interchangeable with like locations, and between vehicles. Panels, linings, masks, trim, and other interior finishing materials shall be manufactured to finished dimensions and installed without modifications, except where specifically **approved**.

14.2.3 Interior Linings

14.2.3.1 General

Select suitable material for linings based on the application, to comply with the requirements below, and to comply with other specified requirements.

14.2.3.2 Performance

Comply with the following:

1. Maximum Deflection:

    a. A centrally applied load of 222 N (50 lb) on a contact area of maximum 2,581 mm^2 (4 in^2) shall not deflect a lining more than 1% of the short span length.

    b. A uniform pressure of 1.44 kPa (30 lb/ft^2) shall not deflect a lining more than 1% of the short span length.

2. Impact Resistance: Linings shall be capable of withstanding 27 J (20 ft-lb) of impact energy applied uniformly over an area of 1,290 mm^2 (2 in^2) without deformation or cracking.

3. Smoothness: Interior linings and moldings shall be free of all undulations. The maximum permitted variation from a designed contour on all interior surfaces shall be 3.2 mm (0.125 in) over 1 m (3.3 ft) in any direction.

14.2.3.3 Walls

Comply with the following:

1. Side Wall Material:

    a. Balanced melamine: Flame retardant (FR) Grade, minimum thickness 3.2 mm (0.125 in)

    b. Thermoplastic sheet: Minimum thickness 3.2 mm (0.125 in) after forming

    c. FRP: Minimum thickness 3.2 mm (0.125 in)

    d. Melamine on aluminum sheet: Minimum thickness of aluminum 2.1 mm (0.081 in), with melamine fused to the aluminum sheet

2. Side Wall Joints:

    a. Maximum one joint per wainscot section between side entrance doors and in each passenger compartment level.

    b. Hide joint from view with seats, where appropriate.

3. End walls, bulkheads, and door pocket panels: Cored construction, as **approved**.

4. Window masks: Provide at vehicle-body windows, including windshields:

    a. Slope masks to eliminate dirt collecting areas.

    b. Support and cover joints with moldings, or a suitable joint design that eliminates the molding may be proposed.

    c. As an alternate, wide glazing strips may be used which extend to and engage the lining panels.

5. Moldings: Colors of moldings on exposed surfaces shall be compatible with the colors of the other materials in the vehicle.

14.2.3.4 Ceiling

Ceiling between light fixture assemblies:

1. Material: Rigid material meeting the requirements of Section 16, Materials and Workmanship. Material shall not warp from duct condensation. Material shall be **approved** during design review.

2. Finish: Shall match the ceiling cove area in color and texture.

3. Ceiling panels: Individually removable. Provide trim caps between panels.

4. Joints:

    a. Transverse joints: Space no closer than 1220 mm (4 ft).

    b. Longitudinal joints: Not permitted.

5. Support: Ceiling panels may be supported by the air-distributor/light-fixture assemblies and by hinges welded to the roof structure. Hinges shall be no greater than 1015 mm (40 in) apart.

Ceiling Cove Area (outboard of light fixtures):

1. Material:

    a. Melamine-faced aluminum, minimum thickness 2.0 mm (0.08 in).

    b. Molded fiberglass reinforced composite; or **approved** equal.

2. Alternately, panels may be formed by extensions of the window masks, or may be flat diagonal sections, using the above materials.

14.2.3.5 Support and Installation of Interior Linings

Mechanically fasten interior linings to their supporting surfaces:

1. Fasteners shall not be exposed to passengers unless specifically **approved**.

2. Alternates that bond the interior panel to the exterior wall as a unitized replaceable assembly may be proposed.

3. The mounting shall accommodate dynamics of vehicle movement without transmitting stress to the liners.

4. Provide minimum 25 mm (1 in) radius cove at intersecting adjacent surfaces.

5. Provide "anti-squeak" tape between all linings or panels and any structure to which they are attached or with which they come into contact.

14.2.3.6 Access Panels

Provide access panels in the vehicle interior lining where required, and as **approved**. Comply with the following:

1. Interchangeability: Manufacture panels, hardware, and their interface to the vehicle body with sufficient tolerances to allow exchange of panels of like size anywhere in the vehicle.

2. Material: Matching the surrounding lining in color and texture.

3. Latches:

    a. Quick-release fasteners, as specified in Section 16, Materials and Workmanship, or as **approved**.

    b. Exposed to passengers: Self-locking, flush mounted, slam latch that uses the Crew Key; shall include provisions to prevent rattling while the vehicle is in motion.

4. Ceiling Access: Panels and grilles shall be hinged and equipped with safety catches.

5. Equipment Enclosures: See Equipment Enclosures section, below.

14.2.3.7 Equipment Supports

Support equipment directly from the vehicle structure or via hangers welded to the vehicle structure. Ceiling panels and wall linings shall not be used to support equipment or equipment lockers.

14.2.4 Interior Finishes

Comply with the Interior and Exterior Design Package and the following:

1. Interior metals: Painted in accordance with Section 16, Materials and Workmanship, with the following exceptions:

    a. Exposed stainless steel (except for floor covering): Provide an **approved** brushed finish with grain direction arranged to be consistent with the decorative scheme. Paint only as required by the **approved** Interior Design Package.

    b. Aluminum: For interior applications not exposed to passengers, aluminum may be unpainted, but if unpainted shall be anodized in accordance with Section 16 with approval.

    c. High-traffic areas: With SEPTA **approval**.

2. Powder coat: If the **approved** Initial Interior and Exterior Design Package permits interior surfaces requiring paint, provide powder coat in accordance with Section 16. Powder coat may be applied only to items that can be removed for recoating.

3. Gel coating: Shall meet the requirements of Section 16.

4. Durability: Color and finish shall be fade-resistant and shall not change appearance or run when exposed to interior lighting, sunlight, or chemicals typically used to clean vehicles.

5. Graffiti resistance: Shall be graffiti resistant to ASTM D6578/D6578M, using cleaning agents agreed by the Engineer, with a pass rating of 5, minimum.

6. Gloss: Interior surfaces shall have a low-glare finish with a glossometer reading between 4 and 15, per ASTM D523, machine direction, using a 60 degree glossometer, or as outlined in the **approved** Initial Interior and Exterior Design Package.

14.2.5 Articulation

Comply with the following:

1. Design and construct flooring, walls, and other moving components such that their movement creates no audible noise exceeding requirements of Section 2, Design and Performance Criteria, under all conditions, when tested in accordance with Section 15, Testing.

2. Design and size gaps between articulation section wall and ceiling panels to prevent injury. Gaps in the articulation portion of the passenger compartment shall not increase or decrease in width, so as to be hazardous to persons, under any conditions.

14.3 Insulation

14.3.1 Acoustical Insulation

Provide sound- and vibration-damping insulation as required and as specified below:

1. Material:

    a. Resistant to dilute acids, alkalis, greases, gasolines, aliphatic oils, and vermin.

    b. Compliant with flammability, smoke emission, and toxicity requirements in Section 16, Materials and Workmanship.

2. Location:

    a. Provide on inner surfaces of all areas of the structural shell, including sub-floor pans, ends, roof, and side frames, and one side of air duct splitters (if used).

    b. Provide on articulation close off panels and bellows.

3. Installation: Clean and prime surfaces before installation in accordance with Section 16.

4. Alternates that sandwich insulation between interior panels and the exterior wall as a unitized replaceable assembly may be proposed.

14.3.2 Thermal Insulation

Insulate vehicle to ensure that heating and cooling requirements of Section 7, Heating, Ventilating, and Air Conditioning, are met:

1. Material:
    a. Fiberglass: Manufactured from long, textile-type glass fibers drawn from a calcium borosilicate mixture to an average diameter of 9 microns.
    b. Bonding agent: Thermosetting phenolic resin not exceeding 6% by weight.
    c. High-temperature limit: Minimum 230 degrees C (446 degrees F).
    d. Alternates that sandwich insulation between interior panels and the exterior wall as a unitized replaceable assembly may be proposed.
2. Material shall not:
    a. Mold, rot, or sustain vermin
    b. Corrode metals
    c. Settle as a result of vehicle vibration
    d. Have an odor or be capable of absorbing odors
3. Location: Insulate roof, sides, and ends of the vehicle, including inside faces of posts and structural members.
4. Density:
    a. Fill entire volume of the available cavity.
    b. Select density of fiberglass insulation consistent with vehicle-body transmission heat loss/gain calculated in Section 7, Heating, Ventilating, and Air Conditioning.
5. Installation:
    a. Roof: Retain insulation using stainless steel wires or strips.
    b. Side- and end-walls: Retain insulation using spears or other **approved** method. Take steps to ensure that sharp, pointed ends are not a hazard to personnel or maintenance equipment.
    c. Floor:
        - Insulate with two layers of equal thickness of fiberglass separated by a vapor barrier.
        - Place this insulation in the structural floor between the transverse floor beams and fill the entire volume of the available cavity.
        - Insulation shall be compatible with the material used at each insulated location in the vehicle structure.
        - Insulation shall be easily removable for maintenance access.

14.4 Floor Covering

14.4.1 General

Comply with the following:

1. Provide floor covering and accessories that result in a durable, watertight, textured covering for the floor panels and other vehicle structures.
2. Flooring color and pattern will be determined by SEPTA during design review.
3. Floor covering shall be in accordance with 49 CFR 38, Subpart D.

14.4.2 Floor Covering Material

Comply with the following requirements for floor covering material:

1. Rubber material:
    a. Water and chemical resistant.
    b. Fully homogeneous throughout, meeting requirements of ASTM F1344.
    c. Without lumps, depressions, or obvious debris.
    d. Constant thickness, no thin or thick areas, unless finish is other than smooth.
    e. Consistent color and pattern.
2. Flexibility: Flooring shall bend around a 20 mm (0.8 in) diameter mandrel without breaking, cracking, crazing, or showing any change in color.
3. Flammability, smoke emission, and toxicity: In accordance with Section 16, Materials and Workmanship.
4. Static coefficient of friction: Minimum 0.6 measured in accordance with ASTM D2047, using leather and rubber shoe materials meeting these requirements:
    a. Leather shoe material: Federal Specification KK-L-165C
    b. Rubber shoe material: ASTM D1630

14.4.3 Specific Applications

Provide the type of floor material indicated below for the specified locations:

1. Aisles and other walking areas: Non-slip grit surface, as **approved**.
2. Stairs:
    a. Provide each threshold step with a safety nosing resistant to chipping, peeling, and other forms of preliminary failure.

b. Nosing shall extend the full width of the step and contrast visually from the stair tread and riser covering by 70%, as determined by the following formula:

Contrast (%) = [(B1-B2)/B1]*100
Where:
B1 = Light reflectance value of brighter area
B2 = Light reflectance value of darker area

14.4.4 Cove and Trim Moldings

Comply with the following:

1. Cove molding used for floor covering:

    a. Material: Brushed finish stainless steel.

    b. Size: Minimum size consistent with maintenance access to dirt in the corners.

    c. Corners, Splices, Terminations: Formed pieces that rigidly connect to the cove pieces.

    d. Application: Provide between floor covering and vertical surfaces at which, or behind which, the floor covering terminates, such as side walls, end walls, equipment boxes, and floor heaters, including those in the Operator's cab.

2. Trim molding: Provide stainless steel or aluminum molding around the periphery of the floor covering at exposed removable floor access panels and at the edge of the articulation section.

14.4.5 Floor and Molding Installation

Comply with the following:

1. Prepare and install floor as follows:

    a. Preparation:

        - Before installing the floor covering, fill voids, indentations, fastener heads, and separations between floor panels with an **approved** flame-retardant leveling compound.

        - The floor shall be made smooth and flat within 1.6 mm (0.063 in) measured within any 915 mm (36 in) distance in any direction.

    b. Installation: Securely bond floor covering to the floor structure with a waterproof adhesive as recommended by the floor-covering supplier.

    c. Seams: Transverse seams shall not be used. All seams shall be longitudinal.

2. Install molding as follows:

    a. Form a watertight seal with the floor covering and the vertical surface.

b. Alternate:

- Where floor covering meets walls, curve floor covering upward onto walls, providing support in the curve. Radius shall not be less than recommended by floor covering manufacturer.
- Terminate floor covering with an edge sealant or other **approved** method.

14.4.6 Door Thresholds

Provide a threshold at each doorway:

1. The threshold shall be designed to minimize interference with passenger travel.
2. Material: Cast or machined stainless steel.
3. Anti-skid treatment:
   a. Permanently texturized by means of plasma metal spray on exposed top surface.
   b. Static coefficient of friction: Minimum 0.6 measured in accordance with ASTM D2047, using leather and rubber shoe materials meeting these requirements:
      - Leather shoe material: Federal Specification KK-L-165C
      - Rubber shoe material: ASTM D1630
   c. Anti-skid treatment shall be documented to last 20 years of service.
4. Drainage: The design shall be self-clearing in that it shall not allow debris or water to collect in the door guide channel. If the threshold includes longitudinal slots, such as for door tracks, provide drainage to the outside of the vehicle.
5. Installation:
   a. Fasten threshold to vehicle structure with stainless steel fasteners.
   b. Provide sealant underneath and around the full periphery of the threshold.
   c. Fully seal the interface between threshold and mating floor covering.
6. Provide the same type of threshold at single doors that is provided at double doors.
7. Heated: In accordance with Section 7, Heating, Ventilating, and Air Conditioning.

14.5 Passenger Seats

14.5.1 General

Provide heavy-duty, transit-grade seats with removable inserts:

1. Seat materials shall comply with flammability, smoke emission, and toxicity requirements in Section 16, Materials and Workmanship.

2. Materials shall be selected for passenger comfort, durability, and maintainability.

3. Seat materials shall provide a rigid, hard surface.

4. Arrangements shall maximize the number of passengers. Submit general arrangements as part of Section 2, Design and Performance Criteria.

14.5.2 Design Criteria

Incorporate the following requirements in passenger seat design:

1. Seat structure:
    a. Visible:
        - Brushed stainless steel, with 180 grit, horizontal finish.
        - Formed synthetic frames, such as FRP or thermoplastics, may be proposed but shall comply with material requirements and flammability, smoke emission, and toxicity requirements in Section 16, Materials and Workmanship.
        - Color: To be determined by SEPTA during design review.

    b. Non-visible: Powder-coated steel or stainless steel.

2. Seat back pans: Sculptured to give knee room when using transverse seating.

3. Seat inserts: Provide for both seat bottom and backrest.
    a. Contoured for maximum comfort.

4. Comfort and Safety:
    a. Use recognized ergonomic and human factors principles to ensure a comfortable and safe ride for passengers:

    b. Gaps:
        - Design gaps between seats and walls or windows, or back-to-back seats, to prevent pinching injury when the seat moves.
        - Design gaps to restrict the placing of objects, such as sharp objects or rubbish, down the sides or between seats.

5. Maintainability:
    a. Seats shall be easily removable by maintenance staff but not by passengers.

    b. Secure seat frames with maximum six mounting bolts per seat for easy removal and reinstallation. Hide mounting bolts where exposed to passenger view using inconspicuous snap-in covers.

    c. Seat insert bottoms shall be completely interchangeable and detachable by a maximum of two fasteners hidden from passengers.

   d. Seat insert backrests shall be retained by the seat structure and seat bottom insert and detachable only by means of a simple, hidden release mechanism after the seat insert bottom has been removed.

   e. Cleanability under seats shall not require extensive effort or removal of any components.

6. Manufacturer's logos or markings: Not visible to passengers.

14.5.3 Seat Standard

Comply with APTA-PR-CS-S-016-99 for seat construction and attachments to vehicle structure, with the following differences:

1. Section 5.1, Static strength testing: For the following tests, deflection shall be maximum 25.4 mm (1 in), with a permanent set of maximum 3 mm (0.118 in):

   a. 5.1.1, Backrest strength test

   b. 5.1.2, Grab handle strength test

   c. 5.1.3, Vertical seat strength

2. Section 5.2, Dynamic sled testing, and 5.3, Additional dynamic testing: Seats shall be subjected to a 5g crash pulse rather than the 8g requirement. Seats shall remain attached to the vehicle structure and cushions (inserts) shall remain attached to the seats.

14.5.4 Dimensions

Comply with the following dimensions:

1. Total seat pan depth: Minimum 431 mm (17 in), measured from the seat's forward edge to the forward surface of the seat-back.

2. Seat spacing (knee-to-back seats) if transverse seating is used: Minimum 740 mm (29 in), measured from the same point on each seat.

3. Legroom (longitudinal clear distance tangent to the seat pan) if transverse seating is used: Minimum 660 mm (26 in), measured from the front of the seat-backrest to the back of the next seat-back-shell.

4. Individual seat width: 457 to 483 mm (18 to 19 in), which may be achieved through the use of spacers placed between individual seats.

5. Aisle width:

   a. Minimum 635 mm (25 in) between seating on opposite sides of the vehicle.

   b. See Section 2, Design and Performance Criteria, for special requirements related to width of Accessible Onboard Circulation Paths for access to mobility aid parking areas.

14.5.5 Flip-Up Seats

Where flip-up seats are provided in mobility aid parking areas, comply with the following:

1. Seat back: Similar in shape and contour to standard seat back.
2. Seat bottom: Fold-up type to give space for the mobility aid. When not in use it automatically reverts to the "raised" position. Regardless of the seat bottom position it shall be firmly in place under normal conditions and require no more than 44.5 N (10 lbf) to rotate to deployed, seating position.
3. Supports: Attach to wall and pedestals, or other **approved** arrangement.
4. Area beneath seat: Leave open for easy cleaning.
5. Strength: Installed seat shall withstand a downward vertical load of 1780 N (400 lbf) applied uniformly along the front edge. A permanent maximum set of 3.2 mm (0.125 in) will be permitted under these conditions.

14.6 Mobility Aid Parking Areas

Comply with the following:

1. Quantity: Provide in each vehicle as specified in Section 2, Design and Performance Criteria.
2. Orientation: Design parking areas to locate the mobility aid longitudinally (end facing) in the vehicle.
3. Clear Floor Space: Provide area compliant with 49 CFR 38, Subpart D, for each mobility aid parking area.
4. Maneuvering Circle: Provide a circular maneuvering space clear of obstacles for mobility aids to maneuver in and out of each designated mobility aid parking space. Turning space shall meet the requirements of 36 CFR 1191.304.
5. Securement System: Retractable seat belts shall be provided for each mobility parking area. The securement system shall secure common wheelchairs and mobility aids and shall either be automatic or easily attached by a person familiar with the system and mobility aid and having average dexterity. The securement system arrangement shall be submitted for **approval**.

14.7 Interior Equipment

14.7.1 Standing Passenger Safety Devices

14.7.1.1 Stanchions, Handrails, and Grab Rails

Provide stanchions, handrails, grab rails, grab handles, and handholds (as defined in Section 1) and related fittings complying with the following requirements:

1. Regulations: Comply with 49 CFR 38, Subpart D.
2. Material:
   a. Stainless steel with an **approved** finish. Surfaces shall be smooth and free of sharp edges that might injure passengers.
   b. If exposed stainless steel, finish shall be 180 grit circumferential.
3. Dimensions:
   a. Diameter: 32 to 38 mm (1.25 to 1.5 in).
   b. Knuckle Clearance: Minimum 38 mm (1.5 in).
4. Placement:
   a. Standing passenger positions: Provide stanchions within 760 mm (30 in) of possible standees, but in locations that do not interfere with access by mobility devices. Provide handholds where stanchions are not possible.
   b. Boarding area: Do not place stanchions between windscreens, except they may be located on the inboard edge of each windscreen.
   c. Transverse seats: Provide grab handles, grab rails, or stanchions at each aisle seat.
5. Mounting:
   a. Fasteners: Tamper-resistant stainless steel.
   b. Orientation: Select and locate attachment points, including seat attachments, such that there is no visual divergence from vertical or horizontal, as appropriate, from all viewpoints.
   c. Stanchions:
      - Rigidly mount to the floor, wall support structure, or seat grab rails.
      - At upper end, mount stanchion only to vehicle structure.
      - Mount such that no rattling or noise is produced during operation.
      - Design such that stanchions give no support for the ceiling, roof, or any other component, and make no contribution to vehicle-body structural design.
   d. Grab rails: Design without the need for lateral supports.

6. Strength: Shall withstand applied loads of 1330 N (300 lb) in any direction without permanent deformation and without transient deformation that would pinch or injure.

7. Mobility aid area:

   a. Provide at least one horizontal handrail positioned 685 mm (27 in) above the floor.

   b. Provide stanchions, handrails, or other safety devices to allow safe use of this area by standees when no mobility aids are present.

14.7.1.2 Spring Loaded Grip Handles

Comply with the following:

1. Material: Stainless steel or alternate material as **approved**.

2. Spacing: Maximum 800 mm (31 in).

3. Location: Attached to longitudinal handrails, distributed evenly throughout the vehicle in locations where no immediate vertical stanchions exist for shorter passengers to reach.

4. Operation: Spring returned flip grip handles.

14.7.2 Windscreens

14.7.2.1 Description and Location

Provide layouts and 3D renderings in accordance with Section 2, Design and Performance Criteria. If windscreens are **approved**, they shall be as follows:

1. Purpose: To define the boarding area and minimize drafts of external air onto passengers near the door and outside of the boarding area.

2. Description: Solid lower panel with a transparent upper panel above the level of lower-side window edge, and a stanchion on the inboard side.

3. Location: At each passenger door location.

4. Accessible Boarding: At locations where a windscreen may interfere with accessible boarding, it may be reduced in size or eliminated with **approval**.

14.7.2.2 Material and Assembly

Material and assembly of windscreens shall comply with the following requirements. Glass specified in this section shall conform to all requirements of the Windows section, except for UV and solar heat gain requirements:

1. Material:

   a. Lower panel: Rigid material meeting the requirements of Section 16, Materials and Workmanship, and **approved** during design review.

b. Upper panel:

- Clear safety glass, laminated, with a rigid frame, or tempered, with or without a rigid frame, minimum thickness 6.4 mm (0.250 in), with an **approved** vandal-resistant window film applied to both surfaces.
- If the upper panel is without a frame, the panel edge shall be ground smooth with edges seamed in accordance with SAE J673, Edge No. 4.

2. Assembly:

a. Attach the upper panel flush to the top of the lower windscreen panel and to sidewall.

b. Attach the upper edge of the frame or tempered glass panel to the windscreen stanchion.

3. Dimensions:

a. Top edge of upper panel: Minimum 1830 mm (72 in) above floor.

b. Between upper panel and windscreen stanchion: Minimum 64 mm (2.5 in) for hand clearance.

c. Lower panels adjacent to high floor areas shall extend to the top of the high floor section wainscot area, with upper panels above.

d. Windscreens adjacent to mobility aid parking areas may be of reduced width to allow mobility aid maneuvering room.

14.7.3 Bicycle Racks

Provide bicycle stowing racks as specified in Section 2, Design and Performance Criteria:

1. Type: As **approved**.
2. Size: For 29-inch bicycle model.
3. Material: Stainless steel (all visible components).
4. Mounting:

a. As close to the interior sidewall as possible, to minimize bicycles protruding into the passenger aisle.

b. Bicycle retention equipment and bracketry shall in no way hinder or impede the approach or use of the area by a wheelchair.

c. The device shall not impede passenger flow in the stored position.

5. Strength:

a. Assume the weight of a stowed bicycle is 23 kg (50 lb)

b. Each single bicycle bracket and its mountings and supports shall withstand, without permanent deformation, the following individually applied design static load factor's action on the mass of the bicycle stowed, combined with the mass of the bicycle bracket (hook):

- Longitudinal: 5g
- Vertical: 4g
- Lateral: 4g

14.7.4 Fare Collection Equipment

14.7.4.1 General

SEPTA will furnish fare collection equipment for installation in the vehicle by the Contractor, as specified below.

Incorporate provisions for installation of the following:

1. Ticket Validators
2. Ticket Vending Machines (TVMs)

14.7.4.2 Fare Collection Equipment Provisions/Installation

Ticket Validator and TVM:

1. Location/Quantity: One located in each double door area, or at other **approved** location
2. Stanchions: Provide for mounting ticket validator and TVM and to prevent passengers from using the fare collection equipment as a leaning post.
3. Horizontal passenger assist: Provide between boarding passengers and fare collection devices in compliance with 49 CFR 38.77.
4. Strength: Installed equipment shall withstand applied loads of 1330 N (300 lb) in any direction.
5. Power/Network Connections:
    a. Provide electrical power from a dedicated circuit breaker located in the electrical locker to each ticket validator and TVM.
    b. Provide network connection to each ticket validator and TVM as specified in Section 13, Vehicle Communication Systems.
    c. Hide all cabling in the stanchion, or via other **approved** methods.

14.7.4.3 Fare Collection Equipment Testing

Test Ticket Validators and TVMs before delivery of the vehicle, in accordance with Section 15, Testing.

14.7.5 Portable Device Charging

Comply with the following:

1. Provide charging stations for portable device charging locations in the passenger areas within the vehicle.

2. Charging Ports: USB standard-A. Other industry standard ports such as USB standard-C may be proposed for **approval**.

3. Locations: Proposed by the Contractor, based on seating arrangements proposed in Section 2, Design and Performance Criteria, for review and **approval**.

14.7.6 Provisions for Equipment Specified in Other Sections

Other sections define equipment that shall be accommodated in the design of the vehicle interior. Typical equipment includes the following:

TABLE 14-1, TYPICAL EQUIPMENT	
Passenger Stop Request	Section 6, Passenger Doors
Passenger Intercoms	Section 13, Vehicle Communication Systems
Information Signs	
PA speakers	
Surveillance cameras	
Automatic Passenger Counting equipment	

Provide mounting space, brackets, wiring, connectors, and related components for all specified equipment. Install and test such equipment, where specified.

14.8 Keys and Locks

Comply with the following:

1. Provide keys operable in new vehicles.

2. Provide the following three types of keys for access to various vehicle equipment or controls:

    a. Master Controller Key:

    - Barrel style key cut to a code assigned to SEPTA
    - Chicago Lock, Model Number, ACE II, No. 4072-1-DC

    b. Crew Key

    c. Maintenance Key

3. Keys and locksets shall be readily obtainable from US domestic sources.

4. Keys and locksets shall be assigned as shown in Table 14-2, Key Assignment Table, below, or as agreed during design review. Other locks and keys may be required that are not listed, and they will fall into one of these two categories:

   a. Crew Key: Access panels or controls intended for Operator access or operation.

   b. Maintenance Key: Access panels or controls intended for maintenance access or operation only.

TABLE 14-2, KEY ASSIGNMENT TABLE

Name	What the key operates/opens
Master Controller Key	Master Controller key switch
Crew Key	Crew door switch
	Exterior manual door release
	Manual door release mechanism reset device
	Cab electrical lockers with circuit breakers
	Cab via the cab door
	Operator's storage locker
	Other electrical lockers
	All overhead access panels
	Access panels to under-seat equipment requiring Operator access
	HVAC return air grille
Maintenance Key	Side skirt (for removal)
	Electrical locker with event recorder
	All other access panels
	Cab convenience Outlet cover

14.9 Windows

14.9.1 General

Provide only glazing products that are readily available in the US from North American suppliers, in the sizes and thicknesses provided on the delivered vehicles.

14.9.2 Type and Performance

Comply with the following:

1. Type: Single-glazed, fixed.

2. Glazing: Laminated, tempered safety glass.

3. Standard: Test in accordance with ANSI Z26.1 or **approved** equivalent standard:

    a. "Motor vehicle" applies to the vehicles in this Contract, notwithstanding that vehicles of this type operated only on a rail line are excluded by the standard.

    b. Apply requirements in the standard applicable to buses with comparable types of glazing.

4. Identification: In accordance with ANSI Z26.1, and other appropriate designation.

5. Solar Heat Gain Coefficient (SHGC): As defined by the National Fenestration Rating Council and specified in this Section.

6. Visible light transmittance: As defined by the National Fenestration Rating Council and specified in this Section.

7. Distortion: In accordance with ANSI Z26.1 Optical Deviation and Visibility Distortion tests. Test specimens shall comply with requirements for both optical deviation and visibility distortion to meet this requirement.

8. Glazing treatments: Permanent, within the glazing or in the center membrane. Surface films are not permitted.

9. UV blockage: Minimum 99% for both UVA and UVB.

10. Corners and edges: Ground smooth with edges seamed in accordance with SAE J673, Edge No. 4.

14.9.3 Installation

Mount glazing directly to the vehicle structure with neoprene glazing strips:

1. Lace glazing strips from outside of vehicle.

2. Join together ends of glazing strip by the hot vulcanization process or an **approved** gluing process, to form an endless glazing strip.

3. Ensure glazing rubber channel sizes conform to standard US glazing sizes.

4. Provide established US sources for glazing rubber materials.

14.9.4 Cab Windshield

Provide a windshield in each cab:

1. Standard: In addition to ANSI Z26.1, windshields shall comply with testing requirements for 49 CFR 223 Type I glazing.

2. Tinting: None

3. Parallel luminous transmittance: Minimum 0.70, visible light at normal incidence.

4. Solar heat blocking: Lowest SHGC rating consistent with minimum 0.70 transmittance, using the most technologically advanced low emissivity products.

5. Embedded electrical defrosting: As specified in Section 7, Heating, Ventilating, and Air Conditioning.

6. Design/Installation: Shall minimize external glare, and reflections from inside the vehicle when the vehicle is operated at night with the passenger interior lighting in use.

7. The upper portion of the windshield may cover the end destination sign. Tinting is allowed in that area to cover the surrounding area, if required.

14.9.5 Cab Side Windows

Provide side windows in each cab:

1. Standard: In addition to ANSI Z26.1, cab side windows shall comply with testing requirements for 49 CFR 223 Type II glazing.

2. Type: Horizontal sliding, with latch.

3. Tinting: None.

4. Parallel luminous transmittance: Minimum 0.70, visible light at normal incidence.

5. Solar heat blocking: Maximum 0.47 SHGC.

6. Window frame: Satin finished anodized aluminum, opening, with a latch operable from inside the cab only; weather stripped; reinforced for hard usage; designed to eliminate rattling in all positions.

14.9.6 Passenger Section Side and Door Windows

Provide side and door windows in the passenger section:

1. Thickness: Minimum 6.35 mm (1/4 in).

2. Tinting:

   a. Use only if it is not possible to achieve the specified SHGC by using the most technologically advanced low emissivity products without tint.

   b. Color (if used): Gray.

3. Visible light transmittance: Minimum 0.70. Lower light transmittance may be considered if SHGC values of less than 0.47 can be attained.

4. Solar heat blocking: Maximum 0.47 SHGC.

5. Protection: Provide an **approved** multiple-layer vandal-resistant window film on window interiors.

14.10 Operator's Cab

14.10.1 General

Provide a full-width, fully-enclosed Operator's cab at each end of the vehicle, as specified in Section 5, Operator's Cab Controls.

14.10.2 Size Range of Operators

Design cab for use by an Operator in the size range of the fifth-percentile female to the ninety-fifth-percentile male of the general population as defined by *The Measure of Man and Woman: Human Factors in Design* ("*Measure of Man and Woman*").

14.10.3 Cab Layout

Design cab layout to meet the following criteria:

1. Comply with the design principles of *Measure of Man and Woman*.
2. Operator's forward view shall not be obstructed while standing or sitting.
3. The cab shall be free of sharp edges, protruding objects, safety hazards and floor obstructions.
4. Areas in which paper and other debris can accumulate are not permitted.
5. Ensure that height to underside of console is sufficient to accommodate largest specified Operator, and distance to controls accommodates smallest specified Operator.
6. Coordinate seat dimensions, console height, clearances to comply with design requirements.

14.10.4 Visibility Requirements

Comply with the following:

1. Design cab to allow maximum possible field of view in all directions and minimize reflection in windows, taking into consideration cab layout and design of windshield, corner posts, cab liner color, and cab side windows.
2. Provide the following Operator view as a minimum, allowing for all possible Operator seat adjustment positions and an Operator within the specified size range:
    a. Upward view of minimum 20 degrees.
    b. Downward view sufficient to see a 1.0 m (3 ft-3 in) tall person standing 0.5 m (1 ft-8 in) from the front-most surface of the vehicle without the need to bend at the waist.
    c. Ability to directly or indirectly locate tow bar while at the same time accessing controls during coupling operation (standing is permitted for this activity).

14.10.5 Cab Partition

Provide a full width, transverse partition for the rear wall of the cab enclosure:

1. Material: Rigid material meeting the requirements of Section 16, Materials and Workmanship. Shall be **approved** during design review.
2. Finish and texture: Shall match side wall linings.
3. Attachment: Fasten securely to vehicle roof structure, floor, and vehicle-body side structure, not to ceiling panels or side-lining panels.

14.10.6 Cab Door

Comply with the following:

1. Provide a hinged or sliding door in the cab partition:
   a. Material: Rigid material meeting the requirements of Section 16. Shall be **approved** during design review.
   b. Finish and texture: Shall match cab partition or as **approved**.
   c. Hinge (if provided): Full length, stainless steel, piano-type.
   d. Door swing (if hinged): Into the passenger compartment. Provide a rattle-free latching device to retain against the cab partition.
   e. Tamper-proof construction: Design and construct door and frame such that passengers cannot gain access when door is locked.
2. Provide door latching and locking hardware as follows:
   a. Material: Nickel-bronze or stainless steel.
   b. Inside Cab: Rapid door lock release mechanism that allows the Operator to quickly find it under poor lighting conditions and allows the door to be opened without use of a key.
   c. Operation: Door shall automatically latch and lock when closed.
   d. Key: Lock shall be unlockable from passenger side with a key (see Table 14-2, Key Assignment Table).
3. Provide a grille in the lower portion of door for ventilation: Louvered, sight-tight, of sufficient strength to prevent it from being inadvertently damaged.
4. Provide kick plates along the bottom portion of door on inside and outside face:
   a. Material: Stainless steel
   b. Dimensions: Minimum 0.76 mm (1/32 in) thick and 200 mm (8 in) high

5. Provide a sash window to allow Operator to look into passenger compartment:

   a. Location: Align bottom edge of window with bottom edge of side windows

   b. Glass: Minimum 6.4 mm (1/4 in) thick laminated safety glass

   c. Frame: Rigid material meeting the requirements of Section 16, Materials and Workmanship. Fully support frame with cab door panel on all sides to prevent intrusion

   d. Tinting: Adequate to prevent glare on the windshield from passenger area lighting at night

   e. Operation: Vertically sliding

   f. Latch: Lockable spring latch in the up (closed) position, operable only from within the cab

   g. Protection: Provide an **approved** vandal-resistant window film on surface of window facing passenger compartment

   h. Window curtains: Designed to block light from entering cab from passenger compartment

14.10.7 Cab Console

14.10.7.1 Cab Console Design

Design the Cab Console to accommodate all controls and indicators specified in Section 5, Operator's Cab Controls, and others as needed per the Contractor's design:

1. Slope console surfaces toward the Operator at angles suitable for the layout requirements of Section 5.

2. Design materials and orient surfaces to avoid glare on the windshield interior or any other adverse visual distraction.

3. Design size and shape taking into consideration the layout of controls and indicators specified in Section 5.

4. Permit easy Operator access to both cab side-windows.

5. Design so that liquid spilled on the surface will not pool or collect, and will not damage or interfere with operation of the components or back-panel wiring.

14.10.7.2 Cab Console Material and Finish

Comply with the following:

1. Console Cabinet Material:

   a. Melamine faced aluminum, integrally colored;

   b. Fiberglass reinforced polyester resin; or

   c. Thermoplastic sheet.

2. Console Cabinet Color: Match adjacent cab lining materials.

3. Operating Face Material:

    a. Anodized aluminum: Corrosion resistant, cigarette burn resistant, covered with replaceable films in high-contact areas; or

    b. Melamine faced aluminum: Integrally colored.

4. Operating Face Finish:

    a. Black, non-reflective, non-glare.

    b. Cleanable with soap and water solution.

14.10.7.3 Cab Console Construction

Comply with the following:

1. Maintenance Access:

    a. Provide a piano-type hinge along the lower edge of the console face panel to facilitate replacing switches or repairing wiring.

    b. Provide wire dress and slack that allows full horizontal opening without wire strain.

2. Fasteners: Shall not be visible on the console face.

14.10.7.4 Master Controller Area of Cab Console

Comply with the following:

1. Location: To the left of Operator’s seat.

2. Armrest: Upholstered, padded, ergonomically designed for comfort during long periods of use.

14.10.7.5 Operator’s Handhold

Provide a formed tubular handle attached to the front edge of the Cab Console to give support for Operators:

1. Material: Stainless steel.

2. Strength: Handle, attachment method, and console structure shall withstand repeated use by the 95% percentile male without loosening or damage to the console over the life of the vehicle.

14.10.8 Cab Furnishings and Equipment

14.10.8.1 Cab Flooring

Subfloor: Same as provided in the passenger section.

Floor covering: Same as provided in the passenger section.

14.10.8.2 Operator Seat

Provide a rail-service-proven Operator's seat in each cab meeting the following requirements, located on the vehicle's longitudinal centerline:

1. Design principles: Comply with *Measure of Man and Woman*.
2. Size: Design for the specified size range of Operators (see Size Range of Operators section, above).
3. Foot and leg space: The area under the Cab Console and above the floor shall be clear of all piping and obstructions to provide room for the Operator's feet and legs.
4. Footrest: Adjustable, or flip-down type for use by smaller Operators.
5. Seat frame: Corrosion-resistant tubular construction, designed for hard vehicular usage.
6. Seat and back cushion: Low-smoke silicon foam; the seat cushion shall be minimum 100 mm (4 in) thick.
7. Seat covering: Transportation-grade material meeting the requirements of Section 16, Materials and Workmanship. Material shall be breathable to minimize perspiration buildup and Operator discomfort.
8. Armrests (both sides of seat): Flip-up type.
9. Seat belt:
   a. Provide lap belt (for pelvic restraint) seat belt in accordance with the relevant sections of 49 CFR 571.209.
   b. Provide seat belt assembly anchorages in accordance with the relevant sections of 49 CFR 571.210.
10. Manual seat adjustments, with controls easily operable from a seated position:
    a. Vertical, forward, and backward directions.
    b. Seat back angle.
    c. Seat back lumbar support.
    d. Swivel: Minimum plus or minus 30 degrees from the forward-facing position, with a lock that engages automatically in the forward-facing position and prevents further turning.
11. Attachment: Through the flooring into the underlying vehicle structure and designed to withstand normal usage without failure or loosening over the life of the vehicle.
12. Replacement availability: Shall be a commercial off-the-shelf unit with replacements available domestically.

14.10.8.3 Standing Space

Provide a standing space in each cab for trainer to observe Operator activities during training:

1. Location: Designed to permit trainer to face forward comfortably and not interfere with the operation of the vehicle.

14.10.8.4 Air Comfort System

Provide each cab with Operator-controlled heating and cooling, as specified in Section 7, Heating, Ventilating, and Air Conditioning.

Provide cab windshield and side window defrosting and demisting as specified in Section 7.

14.10.8.5 Sunscreens

Provide adjustable sunscreens as needed to aid the Operator in all external light conditions, including simultaneous front and side sunlight:

1. Screens shall be service-proven in a similar transit application with respect to material, mounting, and adjustment.
2. The sunscreen material shall not neutralize the color of traffic control signals.
3. Consider the following design factors:
    a. Window size and arrangement
    b. Operator position
    c. Color
    d. Light blockage ratio

14.10.8.6 Windshield Wiper and Washer

Provide an electric windshield wiper (or wipers) for each cab windshield:

1. Wiper drives, mechanisms, blades, and controls shall be an integrated system, presently in use in similar applications.
2. Wiper blades and rubbers are considered consumables and shall be commercially available in the US.
3. Wipers shall sweep minimum 80% of the width and 60% of the height of the total windshield area over one complete cycle.
4. Wiper controls shall include variable speed and interval operation to suit a wide range of rainfall conditions.
5. When not active, wipers shall automatically park at a secure and unobtrusive location.

Provide fluid-dispensing windshield washers:

1. Washer nozzle: Attached to each wiper blade such that it moves with the blade.
2. Washer fluid reservoir:
   a. Readily accessible for refilling from vehicle exterior.
   b. Minimum usable capacity 8 liters (2 gallons).

14.10.8.7 Interior Mirror

Provide one or more adjustable interior mirrors in each cab:

1. Locate so Operator can view the passenger compartment
2. Mirror: Distortion-free glass with minimum 360 cm^2 (56 in^2) reflecting area
3. Frame: Cover edges

14.10.8.8 Convenience Outlets

Provide one duplex convenience outlet in each cab:

1. Location: As **approved**.
2. Receptacle: Ground fault circuit interrupter (GFCI) protected, rated 120 Vac, 20 A.
3. Circuits: Provide a dedicated circuit breaker for each outlet.
4. Securement: Secured with keyed lock to prevent access by Operator. See Table 14-2

14.10.8.9 Operator's Tools

Provide mounts for Operator's tools:

1. Location: As **approved**.
2. Tools:
   a. Switch iron, furnished by SEPTA
   b. Pantograph crank, provided by Contractor. See Section 9, Electrical Equipment.
   c. Friction brake release pump, provided by Contractor.
   d. Wheel chock, provided by Contractor.
   e. Reflective triangle, provided by Contractor.

14.10.8.10 Fire Extinguisher

Provide fire extinguishers:

1. Type: Marine, with a minimum rating of 4-A:30-B:C, UL listed
2. Capacity: 4.5 kg (10 lb)
3. Quantity: Two total
4. Location: Mount one in each Operator’s cab, accessible to the Operator
5. Mounting: Use a marine-type mounting bracket
6. Signage: Clearly marked in accordance with the Signage section, below

14.10.8.11 First Aid Kit

Provide first aid kit:

1. Type: ANSI Class A Type III first aid kit.
2. Quantity: Two total.
3. Location: Mount one in each Operator’s cab, accessible to the Operator.

14.10.9 Operator’s Appurtenances

14.10.9.1 Coat Hook

Provide a coat hook of **approved** design in each cab on the cab rear partition:

1. Hook: Folding, flush, nickel-bronze
2. Strap: Provide to restrain hanging items

14.10.9.2 Operator's Storage Locker

Provide an easily accessible storage locker in each cab for storing Operator’s personal items while operating the vehicle:

1. Material: Same as that used in construction of the adjacent cab linings.
2. Door: Attached by a stainless-steel piano hinge.
3. Lock: Operable with a key (see Table 14-2, Key Assignment Table).
4. Location: Such that the storage locker door, when in the open position, does not block or interfere with Operator camera.

14.10.9.3 Waste Receptacle

Provide a detachable waste receptacle in each cab:

1. Location: Within reach of Operator when seated.
2. Material: Stainless steel.
3. Design: Leak-proof, designed to accommodate commercially available trash-receptacle liners.
4. Capacity: Approximately 8 liters (2 gallons).
5. Mounting: Secured to prevent rattling when the vehicle is operating.

14.11 Exterior Finishing

14.11.1 Exterior Finishes

Comply with Exterior Design Package and the following requirements:

1. Steel and aluminum: Paint (and powder, where **approved**) in accordance with Section 16, Materials and Workmanship.
2. FRP: Paint in accordance with Section 16 if paint is required by the Exterior Design Package.
3. Stainless Steel:
   a. Exposed to view: **approved** brushed finish or paint, as required by the Exterior Design Package.
   b. Not exposed to view: Need not be painted.
4. Rooftop walking surfaces:
   a. Apply anti-skid coatings to all exterior walking surfaces.
   b. Provide "No-step" markings for areas that are not designed to be walked on.

14.11.2 Paint Colors and Gloss

Comply with the following:

1. The color difference between **approved** color samples and production components shall have a delta E_{cmc} of 1 or less.
2. Provide paint colors, gloss, and finish as follows:
   a. Exterior sides and ends of the vehicle, and roof shrouds:
      - Colors: SEPTA’s standard white with blue accent, as **approved** in the Initial Interior and Exterior Design Package.
      - Gloss level: Minimum 85 as measured with a 60-degree glossometer.

- Orange peel: Minimum level 6.

b. Trucks, traction motors, and gear reducers:

- Color: Black
- Gloss level: Semi-gloss

c. All other areas, including roof surfaces and equipment, underfloor surfaces and equipment, and other areas not exposed to view:

- Color: Charcoal gray, or similar
- Gloss level: Semi-gloss

14.11.3 Graphics

Where graphics are required as part of vehicle exterior finishing, comply with the **approved** Exterior Design Package for colors and Section 16, Materials and Workmanship, for material and installation.

14.12 Rain Gutters and Water Drainage

Provide rain gutters or other devices to prevent water drainage over the sides of the main body sections and cab ends:

1. Provide concealed gutter-drainage conduits, which shall empty below the floor line of the vehicle.
2. Size gutters and drainage conduits to prevent accumulated water from overloading the system:
    a. During maximum rainfall rate for the Project area, as specified in Section 2, Design and Performance Criteria
    b. During vehicle acceleration and braking
    c. On grades
3. Gutters: Separately form and attach or make integral with the roof structure via roof sheet corrugations or similar configurations.
4. Drainage conduits:
    a. Construct with no sharp bends
    b. Design for easy clean-out
    c. Provide screens at water entry points
    d. Fully insulate where inside the vehicle-body structure to prevent condensation or leakage
    e. Do not run through equipment lockers except as reviewed and **approved** during design review

14.13 Equipment Enclosures

14.13.1 General

14.13.1.1 Standards

Comply with the following standards as applicable to equipment enclosures:

1. NFPA 130, Chapter 8, Vehicles: Comply with requirements of sections on equipment arrangement, flammability and smoke emission, equipment lockers, electrical fire safety, and other sections with requirements applicable to equipment enclosures.

2. NEMA 250: Comply with specified type requirements, except as specified otherwise in this Section. Where conflicts exist, comply with this Section.

3. IEEE Std 1478: All vehicle electronic equipment enclosures shall be classified according to the environmental locations and equipment classes for design and testing purposes.

14.13.1.2 Construction

Comply with the following enclosure construction requirements:

1. Materials: Provide noncorrosive equipment enclosures constructed of either FRP or stainless-steel. Comply with the requirements of Section 16, Materials and Workmanship. Enclosures constructed of steel hall have continuous welds or **approved** spot welds with fillers along all seams.

2. Stiffeners: Provide welded or bonded-in-place stiffeners for walls and covers of large boxes; comply with high-quality commercial practice.

3. Cover bearing surface: Provide a flat, NEMA-type formed lip as the bearing surface for the cover seal, minimum 3.2 mm (1/8 in) wide.

4. Gasket compression: When closed and latched, covers shall bear on the frame or a hard stop to control gasket compression.

14.13.1.3 Hardware

Latches, hinges, and cover attachment hardware: Stainless steel.

14.13.1.4 Seals and Gaskets

Sealing System:

1. Material: Closed cell neoprene foam, minimum thickness 9.5 mm (3/8 in), resilient, watertight.

2. Attachment: Secure in a channel near the periphery of the cover.

3. Minimum life: 10 years.

4. Compression: The seal shall be compressed maximum 50% with the cover securely fastened.

5. Testing: Sealing system shall pass the water test for equipment enclosures in Section 15, Testing.
6. RFI gasketing: Continuously conductive contact strip. Provide on all equipment boxes and covers containing equipment that could produce RF, including auxiliary power supplies and traction inverters.

14.13.1.5 Labels and Warnings

Provide labels and warning indicators as specified below in Signs and Graphics section.

14.13.1.6 Paint

Comply with the following:

1. Interiors of equipment enclosures shall be primed and painted with white paint.
2. Exteriors and interiors of covers, shall be painted or finished in accordance with this Section and Section 16, Materials and Workmanship.
3. Seals and cover hardware shall not be painted.

14.13.1.7 Location

Comply with the following:

1. Locate enclosures for control and other critical equipment to ensure protection against environmental contamination and mechanical damage.
2. Locate and orient enclosures and covers such that:
    a. Covers can be opened at least 90-degrees without interference with other equipment.
    b. Enclosure openings and space in front of the enclosure allow access to all internal equipment, and allow inspection, repair, and replacement equipment without disassembly or removal of other equipment.
3. High-voltage dc equipment enclosures are prohibited inside the passenger compartment.

14.13.2 Exterior Equipment Enclosures

14.13.2.1 Material and Construction

Comply with the requirements of the General section, above, and the following requirements specific to exterior equipment enclosures, which include underfloor- and roof-mounted equipment enclosures:

1. Construction:
    a. Watertight: When subjected to pressure wand cleaning and driving rain, except where equipment must be ventilated; NEMA Type 4.

   b. Drainage: Provide for discharge of condensation and leakage due to damaged or deteriorated seals. Provide with cotter keys or other **approved**, simple drain clearing mechanisms.

   c. Cover bearing surface: Provide a flat, NEMA-type formed lip as the bearing surface for the cover seal, minimum 3.2 mm (1/8 in) wide.

   d. Gasket compression: When closed and latched, covers shall bear on the frame or a hard stop to control gasket compression.

2. Vents:

   a. Provide where necessary.

   b. Arrange to minimize water entry and deflect direct water spray.

   c. Cover vents with stainless steel screens welded to the inside of the enclosure.

   d. For underfloor enclosures, provide with external shields or baffles to prevent directed water sources, such as from wheel splash, from entering the enclosure.

14.13.2.2 Covers

Comply with the following requirements for exterior equipment enclosure covers:

1. Interchangeable: Provide doors, covers, and access panels that are interchangeable between boxes of the same size and type within a vehicle and between vehicles.

2. Hinged covers (if provided): Readily removable without the use of tools.

3. Latching:

   a. Latch Type: Quick-release type with no separable or non-retained parts.

   b. Latch Clearance: For underfloor enclosures, arrange latches and latch catches so they do not protrude beyond the bottom or edge of the box or cover in latched position and do not violate vehicle dynamic clearance outline in unlatched position.

   c. Seal Relaxation: Latch shall compensate for seal relaxation considering the worst-case condition of hard contact between cover and box. In this extreme case, the latch shall hold the cover firmly to the box without rattling.

   d. Safety Catch: Spring-loaded. Provide at the center of each underfloor box cover. Design to retain cover within vehicle dynamic clearance envelope at all operating speeds up to vehicle design speed without cover latches engaged.

4. Hold-Open Mechanism: Provide on top-hinged underfloor covers and roof-mounted enclosure covers, internal to enclosure:

   a. Cover Removal: Mechanism shall not interfere with or impede easy removal or replacement of cover and shall stay with the cover when the cover is removed.

   b. Mechanism Removal: Easily removable from the cover for replacement.

c. Non-Shorting: When the cover is opened or closed, it shall not be possible for the mechanism to short or ground internal electrical parts.

5. Cover markings: Clearly and permanently mark the cover location and vehicle number on the inside surface.

14.13.2.3 Equipment Arrangement

Comply with the following:

1. Underfloor Equipment Access: Provide ready access from side of vehicle, maintenance pits, and when vehicle is on lifts.

2. Roof-Mounted Equipment Access: Provide from the side of vehicle, maintenance catwalks, or other **approved** locations.

3. Equipment Mounting: Attach equipment to standoffs or subplates welded to the box. Do not attach equipment directly to enclosure walls, top, or bottom using bolts or other fasteners.

4. Clearance: Provide sufficient clearance to protect internal equipment from damage due to minor impacts; minimum 13 mm (1/2 in), between exposed sides and covers of equipment enclosure and internal equipment.

14.13.2.4 Ventilation

Comply with the following:

1. Arrange equipment for maximum ventilation of parts and minimum restriction of cooling air.

2. Divert high-temperature air exhausted from one piece of equipment away from the air intake of other pieces of equipment.

3. Where forced air ventilation is provided, provide a manometer test fitting in an accessible location on each equipment enclosure for measurement of pressurization.

14.13.3 Interior Equipment Enclosures

14.13.3.1 General

Comply with the requirements of the General section, above, and the requirements in this Section specific to interior equipment enclosures:

1. Use: Requires review and **approval** during design review.

2. Construction: Fully enclosed with hinged and latched access covers. Visible enclosures and covers shall match surrounding interior finish and colors, except as specified in the Contract Documents.

3. Access covers: When closed and latched, prevent access to the enclosure at all locations around the cover periphery.

4. Environmental: Enclosures and covers shall be dustproof. Enclosures in areas subject to water ingress, such as near doorways, in the cab, or under-seat, shall be watertight on all faces potentially exposed to water ingress.

5. Access: Equipment shall be readily accessible and shall be removable through the access cover without removal or alteration of enclosure components.

14.13.3.2 Underseat Type

Where **approved**, equipment enclosures may be located under seats:

1. Construction: Stainless steel structural frame faced with sheets of rigidized stainless steel.

2. Access: By flip-up seats for easy removal of equipment.

3. Molding: Provide stainless steel cove molding where seat box meets floor covering.

14.13.3.3 Electrical Locker Type

Enclosures may be located in the cab, adjacent to the articulation, or in the ceiling cove area:

1. Construction: Rugged and secure, using panel materials specified in Section 16, Materials and Workmanship, or constructed from formed sheet metal coated with an **approved** thermosetting powder coating, as specified in Section 16.

2. Access Cover:

   a. Design to be rattle-free during vehicle operation.

   b. Secure with quarter-turn locks, except as reviewed and **approved** during design review.

   c. Secure with a key as specified above in Table 14-2, Key Assignment Table.

   d. Access panels may be used for covers if a full dead-front is provided.

3. Ceiling Cove Location:

   a. Coordinate the design with the need to have card holders above the windows as required by this Section.

   b. Hinge the panels at the top and secure at the bottom with key-operated latches, as specified in Table 14-2, Key Assignment Table, above.

   c. Provide "hold open" devices.

14.14 Signage

14.14.1 General

Provide signage and graphics in each vehicle as specified below. Text shall be in English, Spanish, Mandarin, and Russian.

1. Comply with the following regulations and standards:
   a. 36 CFR 1191, Appendix D, Section 703, Signs (ADA requirements).
   b. 49 CFR 38, Subpart D.
   c. APTA RT-VIM-S-021-10.
   d. APTA RT-VIM-S-022-10.
2. All signage shall use the following to the maximum extent possible:
   a. Standardized information symbols, icons, graphics, and pictograms.
   b. Standardized color, contrast, content, and placement.
3. The front Streetcar block number sign shall be electronic Light Emitting Diode (LED) type and shall be capable of displaying 4 alphanumeric characters (1 through 9 and A through Z) with an ADA compliant display area. The block numbers to be displayed shall be input directly into the destination sign system's OCU and shall be independent of any destination sign message code. This sign shall be mounted on the front dash panel toward the curbside and shall not obstruct driver's view.

14.14.2 Informational Text and Graphics

Provide signs and graphics throughout the vehicle to furnish passengers and operating personnel information regarding operation of the vehicle:

1. Operating personnel use only: Clearly label controls and devices with text.
2. For use by passengers: Label equipment both with text and graphical figures or icons in full compliance with ADA requirements, however infrequently the equipment may be used.
3. Passenger interactive devices: Provide identification and instructions, such as for door pushbuttons, stop request buttons, and passenger emergency stations.

14.14.3 Emergency Exit

Comply with the following

1. Emergency exit and access signs shall contain brief and easily understandable information with consideration for maximum useful field of view in accordance with APTA RT-VIM-S-021-10.

2. Emergency exit/access signage systems shall enable passengers, crew, and emergency responders to make positive visual identification of exit/access points without undue hesitation, delay, or confusion.

14.14.4 Low-Location Exit Path Markers

Comply with the following:

1. Provide Low-Location Exit Path Marking (LLEPM) system as required by APTA RT-VIM-S-022-10.

2. The LLEPM shall use high-performance photoluminescent (HPPL) strips or other product, as **approved**, and shall be based on the artist renderings shown in design review.

3. The LLEPM system shall be tested in accordance with Section 15, Testing.

14.14.5 Typical Signage

14.14.5.1 General

All signage, colors, material, and application details shall be **approved**.

14.14.5.2 Vehicle-Wide Signage

Provide the following signs:

1. No Smoking:

    a. Decals shall include the international symbol for no smoking.

    b. Apply on one bulkhead at each end on diagonally opposite sides of the vehicle in each passenger seating area.

    c. Apply on the exterior adjacent to all side door openings.

2. Keep Feet Off Seats: Apply decal on one bulkhead at each end on diagonally opposite sides of the vehicle in each passenger seating area.

3. For Customer Service and Security, Cameras May Be In Use On This Vehicle: Decal shall include a pictogram of a camera. Apply decals on one bulkhead at each end on diagonally opposite sides of the vehicle in each passenger seating area. If SEPTA chooses to enable audio recording functionality, associated information shall likewise be displayed to notify operator that audio recording is active.

4. BRAKE – EMERGENCY USE ONLY: Apply decal to all emergency brake locations within the passenger area. Provide an additional decal stating: “IT IS IN VIOLATION OF FEDERAL REGULATIONS FOR UNAUTHORIZED PERSONS TO CAUSE AN EMERGENCY BRAKE APPLICATION WHEN NO EMERGENCY EXISTS” in smaller fonts below or adjacent to the main decal.

5. WATCH YOUR STEP: Apply decal to all stairs and doorways. Stepwell riser signs shall consist of a high contrast safety yellow with capital letters in black.

6. FULLY EQUIPPED FRA TYPE II GLAZING: Apply decal to the end bulkhead at each end of the vehicle.

7. Bicycle retention: Apply decal adjacent to the retention device or area. Signage shall identify the device and its associated area and include a simple diagram and text to instruct on the proper use of the device or the technique to properly retain the bicycle.

8. Provide a set of decals for each passenger emergency intercom (PEI) unit in the vehicle and in accordance with Section 13, Vehicle Communications System.

9. 120 Vac receptacles: Identify all 120 Vac receptacles by a decal stating “120 VAC.” Apply the decal either above or below the receptacle based on how they would normally be viewed (above for a receptacle low near the floor, below for receptacles mounted higher).

10. DANGER HIGH VOLTAGE:

    a. Provide signs within electrical lockers where 150 V or higher voltage circuitry exists, per 49 CFR 229.85.

    b. Apply signs to all insulating covers (such as circuit breaker panels) and individual apparatus junction boxes within lockers or maintenance areas meeting the voltage threshold.

    c. Apply signs to each exterior corner containing trainline receptacles for both signal and power. Sign shall be as large as possible made from materials with reflective qualities.

    d. Signs shall comply with ANSI Z535.

11. Carbuilder:

    a. Provide a plate for each vehicle denoting and identifying the carbuilder and its logo.

    b. The plate shall also contain text identifying the vehicle to be the property of the Southeastern Pennsylvania Transportation Authority along with the year of the pilot vehicle acceptance.

    c. The plate shall be stainless steel heavily embossed or engraved with color filled text and logo and be permanently attached on the passenger interior side to the B-end/F-end vestibule end door.

14.14.5.3 Interior Side Door Signage

Provide the following signs:

1. Emergency door release identification and instructions:

    a. Signage shall describe by both graphics and simple instructions the use of the emergency door release as furnished by the door system supplier. The location shall be adjacent to the emergency door release mechanism.

    b. Signage shall also describe by both graphics and simple instructions emergency exiting for both powered and non-powered circumstances.

    c. Materials and descriptive content shall meet 49 CFR 238 requirements.

   d. Provide an additional decal near the emergency door release instructions stating: “IT IS IN VIOLATION OF FEDERAL REGULATIONS FOR UNAUTHORIZED PERSONS TO OPEN SIDE DOORS WHEN NO EMERGENCY EXISTS.”

2. Door exit signs:

   a. Provide two each, applied to each side door.

   b. Apply the first decal centered on the door above the window.

   c. Apply the second decal with its top edge 406 mm (16 in) above the floor and 50 mm (2 in) from the door’s side seal.

   d. Signs shall meet the requirements of 49 CFR 238.

3. Do Not Lean Against Doors At Any Time: Apply decal 76 mm (3 in) below the door window and centered on the door for each side door. The decal shall have a safety yellow background, black bold text, and contain a restrictive pictogram.

4. Door number indicator: Provide a decal for each door. Door numbering shall match that of electrical schematics. Apply adjacent or near door control panels.

14.14.5.4 Exterior Signage

Provide the following signs:

1. Doorways:

   a. DANGER – Do Not Board Moving Train: Apply decal adjacent to all door openings. The decal shall be approximately 4 inches wide and high enough to accommodate the text aligned in a portrait orientation.

   b. Bicycles Welcome: Include a symbol for a bicycle and place adjacent to all door openings that open to a bicycle retention area/device.

2. American flag: Apply decal to ends of each vehicle. The style of the flag shall be flat and rectangular. Left and right-hand versions of the flag shall be used so that during application, the flag’s union (star field) is in the direction of the cab when operating.

3. Exterior identification plates for vehicle side equipment access:

   a. Identify all equipment, cut-outs/isolation valves, drains, etc. by ID plates permanently mounted on the side sill adjacent to the device locations.

   b. Access doors for enclosed equipment accessible from the exterior of the vehicle shall also be identified and have ID plates applied adjacent to the doors.

   c. Interior apparatus located within the exterior access points shall have plates to identify both the apparatus and status of the switch or breaker by position (i.e. Off/On).

   d. Plates shall be stainless steel with heavily embossed, pre-etched and paint-filled characters.

4. Trainline jumper instruction diagram: Show the correct interconnection of all trainline connections at the end of the vehicles. The diagram shall be a stainless-steel plate design with etched and paint-filled illustrations and text. Diagrams shall be permanently installed at each corner of the vehicle adjacent to the trainline connector groupings.

5. Vehicle marking plate: Shall be stamped with the vehicle number, vehicle shell production serial number, actual weight of the total vehicle, weight of the vehicle at each end, and weight of each truck. A marking plate shall be provided in an **approved** location.

14.14.5.5 ADA Accommodation Graphics

Comply with the following requirements for ADA compliant graphics and signs:

1. Apply a standard handicap symbol next to all exterior side door openings where mobility device parking is available. If the particular section of the vehicle does not allow for parking, the symbol shall not be used.

2. Mobility aid parking:

    a. Provide a decal stating the standard SEPTA "Handicapped/Mobility Device Parking Area" adjacent to each flip seat area assigned to mobility device parking. The decal shall include or be accompanied by the international symbol of accessibility (ISA) within the decal.

    b. Include additional instructions to flip up seats to access the parking area.

    c. Locate 1.2 to 1.5 m (48 to 60 in) above the floor or where most logical.

3. Priority Seating: Provide a sign stating the standard SEPTA "PRIORITY SEATING For Persons With Disabilities and Seniors – Yield These Seats" adjacent to each mobility aid parking area. Provide instructions for operating the flip-up seats, where provided.

4. Passenger Stop Request: Sign for the mobility aid parking area passenger stop request switch specified in Section 6, Passenger Doors, with instructions for use.

5. Assistive Listening System:

    a. Provide sufficient number of signs descriptive of the system such that every seat has a view of at least one sign, minimum two.

    b. Audio-frequency induction-loop system: Use internationally recognized hearing loop sign consisting of an ear graphic with a T, and some brief instructions for those unfamiliar with the technology.

6. Other ADA-required signage and information, as they apply to transit applications.

14.14.6 Vehicle Numbering

Provide clearly displayed numbering for each vehicle to aid operating personnel and passengers in reporting vehicle locations or incidents:

1. Number Graphics:
    a. Material:
        - Cab Console: Deeply engraved aluminum powder coated black with the numbers' paint filled in bright white
        - Exterior: Retroreflective
        - Other Locations: Graphic film complying with Section 16, Materials and Workmanship.
    b. Number Font: Helvetica medium type style, or **approved** equal
    c. Number Height:
        - Interior: 90 mm (3.5 in)
        - Cab Console: 19 mm (0.75 in)
        - Exterior: 200 mm (8 in)
2. Numbering Scheme:
    a. Number vehicles sequentially from the first production vehicle to the last, using numbers with up to four digits, as **approved** starting with 9200 for the first vehicle.
    b. Where vehicle numbers are included on an end section (interior and exterior), provide both vehicle number and end-identification letters (A or B).
3. Number Locations:
    a. Interior:
        - Cab: Permanently attached to the Cab Console in each cab.
        - Passenger compartment: Upper part of each cab and articulation bulkhead.
    b. Exterior:
        - Both vehicle ends: Above the windshield, in a location to be **approved**.
        - Both vehicle sides: On each side of vehicle in locations to be **approved**.
4. Roof: Each end, oriented as **approved**. Embedment mounted in a neoprene endless glazing section.

14.14.7 Safety

Provide the following safety warnings and signage:

1. Safety warnings and advisories at doors, articulation sections, and access points to hazardous equipment.

2. Equipment enclosure labels with safety warnings for High Voltage, as appropriate.

3. Safety warnings for arc-flash hazard, based on the arc-flash hazard analysis performed in accordance with Section 9, Electrical Equipment. Apply an arc-flash hazard label on each piece of ac and dc electrical equipment for which NFPA 70E requires a label, in accordance with the **approved** arc-flash hazard label schedule submitted under Section 9, Electrical Equipment.

14.15 SEPTA-Provided Routes, Schedules, and Advertising

Provide frames or similar fixtures in each vehicle to accommodate SEPTA-provided printed-sheet material such as route maps, schedules, advertising, and similar materials that are changed periodically:

14.15.1 Frames

Comply with the following:

1. Design: All frames shall be designed for easy insertion and removal of cardboard placard media.

2. Material: Stainless steel with a brushed finish.

3. Mounting: Screws shall be hidden. No attachments shall be made with wood screws or other fasteners without having a tapped insert or tapping plate integrated into the panel or lining.

4. Locations: As **approved** during interior design reviews, unless otherwise specified.

14.15.2 Interior

Comply with the following:

1. Inspection frames: Provide two-tiered framed pocket holder to hold 215 mm by 280 mm (8-1/2 in by 11 in) component data cards and one polycarbonate single pocket. Frames locations are intended to be within **approved** equipment locker locations.

2. Emergency evacuation instruction decal: Provide space for SEPTA's Emergency Evacuation Instruction decal and propose for **approval**. The decal size will be approximately 500 mm wide by 715 mm high (20 in wide by 28 in high) in size. The decal will be self-adhering; thus, no frame will be required.

3. Passenger information: Frame shall be a single unit consisting of a combination of three frames. The top portion of the frame shall consist of two portrait-oriented, side-aligned frames designed to accommodate 215 mm by 280 mm (8 1/2 in by 11 in) documents or placards. The lower portion of the frame shall accommodate 280 mm by 435 mm (11 in by 17 in) media.

4. SEPTA route: Provide frame for the SEPTA route placard measuring 535 mm wide by 560 mm high (21 in wide by 22 in high).

5. Advertising placard frames: Provide frames for standard advertising placards measuring 535 mm wide by 840 mm high (21 in wide by 33 in high). Locations for advertising frames shall be determined after all frame locations have been assigned, at which time space availability shall determine the location and quantity of frames. Plan on a minimum of six frames per vehicle.

14.16 Mock-up

14.16.1 Mock-up Stages

Furnish and update a half-vehicle mock-up:

1. First Stage:

    a. The first stage mock-ups shall depict the layout and appointments of the specified areas in sufficient detail to permit SEPTA to evaluate the design.

    b. The first stage mock-ups shall be constructed of structurally durable materials, which shall replicate and physically resemble actual vehicle equipment and appointments, and shall withstand and support the weight of actual equipment to be installed during the second stage.

    c. Mock-ups shall also be capable of withstanding extensive foot traffic and supporting a concentrated floor load of several people who will participate in the review of the mock-ups.

    d. All components shall be labeled.

    e. The mock-ups shall be designed as modules to aid in the training of Operators and maintenance technicians.

2. Second Stage:

    a. The second stage mock-up shall consist of replacing the simulated equipment and appointments provided in the first stage mock-up with actual equipment and appointments that will be provided on the vehicles, after **approval** and acceptance of the first stage design.

    b. Mock-ups shall be kept current throughout the design review and pilot vehicle processes.

    c. Following **approval**, the second stage mock-up shall be transported to SEPTA for use in maintenance demonstrations and as a long-term training aid.

14.16.2 Mock-up Elements

The half-vehicle mockup shall depict half of a vehicle, in actual size, to show the spatial relationships of the following elements as a minimum:

1. Cab Console.

2. Cab line of sight and field of view.

3. Each control, switch, and indicator, as specified in Section 5, Operator's Cab Controls.

4. Each display, as specified in Section 5, Operator's Cab Controls.

5. Communication equipment controls and displays, as specified in Section 13, Vehicle Communication Systems.

6. MDS display and controls, if any, as specified in Section 17, Controls, Networks, and MDS.
7. Cab partitions.
8. Full doorway with door panels, bridge plate, and control panels.
9. Seat arrangements with stanchions and handholds.
10. ADA accessible areas with stop request and PEI systems.
11. Articulation section.
12. Typical location of equipment access panels (e.g., HVAC and door operator maintenance access).
13. Glazings.
14. Fare collection system.
15. Maintainability of passenger area.

14.17 Contract Deliverables Requirements List (CDRL)

14-1 Initial Interior and Exterior Design Package
14-2 Interior Design Package
14-3 Walls and Ceiling Design Package
14-4 Acoustical Insulation Design Package
14-5 Thermal Insulation Design Package
14-6 Floor Covering Design Package
14-7 Passenger Seat Design Package
14-8 Mobility Aid Parking Area Design Package
14-9 Stanchions, Handrails, and Windscreens Design Package
14-10 Bicycle Racks Design Package
14-11 Fare Collection Design Package
14-12 Key Design Package
14-13 Windows Design Package
14-14 Operator's Cab Design Package
14-15 Windshield Wiper and Washer System Design Package
14-16 Exterior Design Package
14-17 Rain Gutters and Water Drainage Design Package
14-18 Equipment Enclosures Design Package
14-19 Mock-up

14.18 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

5. Software functional descriptions: Include top level control parameters and values

14-1 Initial Interior and Exterior Design Package:

1. Submit within 60 days after NTP.

2. Initial submittals may be in the form of accurately-colored renderings and models.

3. Include the following:

   a. Interior and exterior color scheme
   b. Finishing
   c. General appearance
   d. Seat cushion material and color/patterns
   e. Seating arrangement
   f. Samples of all finishing materials and the material specifications
   g. Equipment arrangement

14-2 Interior Design Package:

1. After **approval** of the Initial Interior and Exterior Design Package, submit a comprehensive interior design package.

2. Include everything related to the interior that was included in the Initial Interior and Exterior Design Package, but in final form.

3. Paint (if paint is **approved** for interior):

   a. Manufacturer's data for each type of painting material with the following information:

      - Composition
      - Recommended application procedures for substrates on which it will be applied
      - Curing characteristics
      - Recommended minimum and maximum dry film thickness
      - Performance characteristics

   b. Detailed paint procedure for all items to be coated.
   c. Paint coating and application document containing the following maintenance information:

      - Procedures for surface cleaning and preparation, priming, surfacing, and painting for equipment that is painted, whether by itself or by its manufacturers and suppliers.
      - Detailed paint schedule showing equipment painted, paint type and manufacturers, recommended thickness, and other pertinent information.

- After **approval**, include as part of the Maintenance and Servicing Manual specified in Section 19, System Support.

d. Sample of each paint color:

- Apply the same number of coats of primer and final paint as specified for the vehicle.
- Use the same base material to which paint will be applied on the vehicle.
- Include CIE Lch tristimulus values for each paint sample, as measured using D65 (sunlight) light source.

4. Powder coating (if **approved** for interior use):

a. Manufacturer's data on powder coating material.
b. Powder coat applicator's cleaning, preparation, and application procedures, including certification that the procedure is approved by the powder coating material manufacturer.
c. Powder repair procedure specific to the proposed application.
d. After **approval**, include as part of the Maintenance and Servicing Manual specified in Section 19, System Support.

5. Graphics:

a. Informational and safety graphics: Text and graphic layouts.
b. Route maps, schedules, and advertising: Frame materials, retention methods, colors, and related features.

14-3 Walls and Ceiling Design Package:

1. Materials specifications.

2. Thermoplastic (if used): Laboratory test certificates stating that thermoplastic sheet complies with standards and strength requirements specified in Section 16, Materials and Workmanship.

3. Application Instructions.

4. Drawings showing application locations.

14-4 Acoustical Insulation Design Package:

1. Data sheets demonstrating that specified requirements are met.

14-5 Thermal Insulation Design Package:

1. Data sheets demonstrating that all specified requirements are met.

2. Details of method of retention for roof insulation and side and end wall insulation.

3. Details of the vapor barrier required for the floor insulation.

14-6 Floor Covering Design Package:

1. Furnish product data for the following:

   a. Proposed manufacturer and material.
   b. Adhesives
   c. Other products to be used in the floor installation, such as stair nosing, cove molding, and trim molding.

2. Submit samples of the floor material including both smooth surface and ribbed or non-slip flooring.

3. Furnish installation details in plan view showing sheets and orientation, seam-sealing criteria, installation of cove and trim molding, and other details as necessary to show compliance with specified requirements.

14-7 Passenger Seat Design Package:

1. Details of seat materials, including sufficient information to verify compliance with the Specifications.

2. Dimensioned drawings of seats and seat layout.

3. Mounting details.

14-8 Mobility Aid Parking Area Design Package:

1. Dimensioned drawings for mobility aid parking areas showing required clearances.

14-9 Stanchions, Handrails, and Windscreens Design Package:

1. Stanchion and handrail spacing and placement.

2. Details of finish.

14-10 Bicycle Racks Design Package:

1. Calculations demonstrating that strength requirements are satisfied.

14-11 Fare Collection Design Package:

1. Installation location, stanchion arrangement, and mechanical and power/network details.

14-12 Key Design Package:

1. Key Assignment Table similar to Table 14-2, with final key and lockset assignments.

2. Samples.

14-13 Windows Design Package:

1. Data sheets demonstrating that specified requirements are met.

2. Details of how windows are replaced.

3. Details of US suppliers.

4. Windshield:

    a. Details of embedded defrosting with sufficient information to demonstrate that the requirements of Section 7, Heating, Ventilating, and Air Conditioning, are satisfied.
    b. Details of how external and internal glare are minimized for the cab windshield.

5. Sample of each type of window showing color and composition.

14-14 Operator's Cab Design Package:

1. General arrangement drawings of the cab, depicting all features required in the cab:

    a. Plan, profile, and front elevation drawings of the interior, showing all visible features, with dimensions.
    b. Plan and elevation views of Cab Console, including Operator's seat and side windows.
    c. Drawings showing Operator's range of visibility out the windshield, and views through the mirrors:

        - Include cab features affecting visibility, such as vehicle structure, sunscreens, shades, window masks, and display screens
        - Show the specified size range of Operators, while seated
        - Show the seated Operator’s whole body accurately in relation to the console and cab seat, with height adjustment of the Operator’s seat according to both head and knee height
        - Show the seated Operator’s relationship to the Master Controller
        - Show the actual sitting position of the Operator, to the extent possible
        - Show the Operator standing to confirm visibility of the coupler with left hand on the master controller, over the size range of Operators

    d. Panelboard locations.
    e. Convenience outlet locations.

2. Manufacturer’s literature or detailed drawings of the following, as appropriate:

    a. Mounts for switch iron and pantograph crank.
    b. Coat hook
    c. Speedometer/ADU speed command display and related ATP indications, as specified in Section 13, Vehicle Communication Systems.

3. Parts List

14-15 Windshield Wiper and Washer System Design Package:

1. Drawings showing the following:

    a. Components of the windshield wiper and washer system
    b. Windshield wipers in parked position

c. Area swept by the wipers
d. Size and capacity of the washer fluid reservoir
e. Access to the washer fluid reservoir, and location of fill port

2. Narrative describing windshield-wiper controls.

14-16 Exterior Design Package:

1. After **approval** of the Initial Interior and Exterior Design Package, submit a comprehensive exterior design package.

2. Paint:

   a. Manufacturer's data for each type of painting material with the following information:

      - Composition
      - Recommended application procedures for substrates on which it will be applied
      - Curing characteristics
      - Recommended minimum and maximum dry film thickness
      - Performance characteristics

   b. Detailed paint procedure for all items to be coated.
   c. Paint coating and application document containing the following maintenance information:

      - Procedures for surface cleaning and preparation, priming, surfacing, and painting for equipment that is painted, whether by itself or by its manufacturers and suppliers.
      - Detailed paint schedule showing equipment painted, paint type and manufacturers, recommended thickness, and other pertinent information.
      - After **approval**, include as part of the Maintenance and Servicing Manual specified in Section 19, System Support.

3. Powder coating (if **approved** for use):

   a. Manufacturer's data on powder coating material.
   b. Powder coat applicator's cleaning, preparation, and application procedures, including certification that the procedure is approved by the powder coating material manufacturer.
   c. Test data to demonstrate suitability for the proposed application, including saltwater spray testing to ASTM B117 on samples of the same substrate, cleaning, preparation, and application procedure proposed. The test result shall show that the coating passes 1,000 hours with no corrosion.
   d. Powder repair procedure specific to the proposed application. After **approval**, include as part of the Maintenance and Servicing Manual specified in Section 19, System Support.

4. Drawings:

   a. Show the final exterior color scheme.
   b. Include detailed drawings of graphics.

      - Informational and safety graphics: Text and graphic layouts.

- Vehicle numbering: Locations, font, and size.

5. Samples:

   a. Paint color:

      - Apply same number of coats of primer and final paint as specified for vehicle.
      - Use same base material to which paint will be applied on vehicle.
      - Include CIE Lch tristimulus values for each color sample.
      - Roof: One sample with anti-skid paint and one without.
      - Trucks: Sample demonstrating that paint does not hide structural cracks.

   b. Graphics:

      - Small graphics: Sample of each graphic.
      - Large graphics: Sample of each color.

14-17 Rain Gutters and Water Drainage Design Package:

1. Detail drawings showing material and dimensions.

2. Calculations confirming size of gutters and drainage conduits is adequate for rainfall rate.

14-18 Equipment Enclosures Design Package:

1. Shop drawings and data sheets demonstrating that all specified requirements are met.

2. Details of stiffeners for large boxes.

3. Detailed equipment arrangement with a maintainability analysis including computerized simulations.

14-19 Mock-up:

1. Deliver and set up at a location as agreed by SEPTA.

14.19 Referenced Standards

The following standards are referenced in this Section:

36 CFR 1191, Appendix D	Technical
36 CFR 1191.304	Turning Space
49 CFR 38 Subpart D	Light Rail Vehicles and Systems
49 CFR 38.77	Interior circulation, handrails and stanchions
49 CFR 223	Safety Glazing Standards--Locomotives, Passenger Cars and Cabooses
49 CFR 229.85	High Voltage Markings

49 CFR 571.209	Standard No. 209, Seat belt assemblies
49 CFR 571.210	Standard No. 210, Seat belt assembly anchorages
49 CFR 571.222	Standard No. 222, School bus passenger seating and crash protection
ANSI Z26.1	Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways - Safety Code
ANSI Z535.1 - 6	Set of six ANSI Safety Standards relating to the design, application, and use of safety signs, colors, and symbols
APTA-PR-CS-S-016-99	Standard for Passenger Seats in Passenger Rail Cars
APTA RT-VIM-S-021-10	Emergency Signage for Rail Transit Vehicles
APTA RT-VIM-S-022-10	Low-Location Exit Path Marking
ASTM D523	Standard Test Method for Specular Gloss
ASTM D1630	Standard Test Method for Rubber Property—Abrasion Resistance (Footwear Abrader)
ASTM D2047	Standard Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine
ASTM D6578/D6578M	Standard Practice for Determination of Graffiti Resistance
ASTM F1344	Standard Specification for Rubber Floor Tile
IEEE Std 1478	Environmental Conditions For Transit Railcar Electronic Equipment
Federal Specification KK-L-165C	Leather, Cattlehide, Vegetable Tanned and Chrome Retanned, Impregnated, and Soles
NFPA 70E	Standard for Electrical Safety in the Workplace
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems
NEMA 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
SAE J673	Automotive Safety Glazing Materials

Tilley AR. 2001. The Measure of Man and Woman: Human Factors in Design. Wiley.

END OF SECTION

Table of Contents

15.1 General

15.1.1 Scope

Test the vehicle and all its components to verify compliance with Contract-specified design, performance, reliability, and maintainability requirements.

This Section is meant to compliment testing requirements specified in other sections of the Specifications. The following elements apply:

1. Perform tests specified in this Section and other sections as specified unless specifically waived by the Engineer.

2. All tests shall be conducted by the Contractor at its expense. SEPTA will provide test vehicle operating crews and all other individuals required by SEPTA policies at its expense. Conduct these tests at such times and on such portions of rail lines as mutually determined by the Engineer and Contractor. Subject each vehicle to all tests to show compliance with the specified performance.

3. The Contractor shall ensure that all test procedures and reports are formally reviewed and approved for validity and reliability by its engineering department prior to their submittal to the Engineer.

4. Whenever test requirements overlap, the more restrictive shall govern. Any components, subsystems, or systems not specifically listed in the following sections shall be completely tested by the Contractor. Test procedure and report requirements shall also apply to these tests.

5. If test procedures or reports are inadequate and do not meet the requirements of the Specifications, the Engineer reserves the right to require additional plans, procedures, details, and schedules to ensure that the test program or report is adequate and does meet the Specification requirements.

6. The **approval** of the Engineer does not in any way relieve the Contractor of responsibility for the adequacy of the test program within the scope of the Specifications.

7. Perform tests on production components without modification or special preparation.

8. Material test requirements may also appear in Section 16, Materials and Workmanship.

9. Other test requirements may appear in other sections of the Specifications.

15.1.2 Equivalent Testing

The Specifications allow for the performance of equivalent testing on systems and components, if it is **approved** by the Engineer and meets the following criteria:

1. Evidence of satisfactory completion of prior tests, as determined by the Engineer, may be sufficient to meet the requirements of this Section, although certain tests shall be performed regardless of prior testing as determined by the Engineer.

2. The following will disqualify existing tests:

    a. Design or material changes have been made to the items under test.

    b. The items are produced in a different facility.

    c. The requirements are different.

    d. Reports of such equivalent testing are dated more than three years before Notice-to-Proceed (NTP) for this Contractor.

15.1.3 Witnessing and Notification

The Specifications require that SEPTA may, at its option, witness all tests. In support of this requirement, the following shall apply:

1. The Contractor shall perform all required tests under Engineer observation.

2. Minimum 30 days before each test, notify the Engineer in writing of the date, time, and location of the test.

15.1.4 Performance of Tests

Comply with the following:

1. Test procedures shall be approved by the Engineer prior to performing any test. No test will be considered valid until the test procedure is **approved** and the respective test report has been received and **approved** by the Engineer. Testing activity scheduled or conducted before test procedure **approval** will be at the Contractor’s risk.

2. The Contractor’s engineering department shall be responsible for providing assistance and expertise during performance of tests.

3. All contractual tests shall be conducted in accordance with Engineer-**approved** test procedures.

4. Under no condition, whether expressed or implied, shall the Contractor be allowed to perform pre-delivery dynamic or static tests on SEPTA property.

15.1.5 Failure of Tests

In the event of a failure to meet the Specification requirements in any test, necessary corrections shall be made by the Contractor at its expense, and the failed test shall be rerun in its entirety at the Contractor's expense.

1. The correction test on the repaired/replaced component shall be repeated until successful

2. For fatigue life test failures:

    a. Identify each indication of a crack, regardless of size, after each cycle displaying how deep, long, and if it increases in size after additional cycling of fatigue testing.

b. The test report shall include a drawing with the locations of all indications identified by a number. The report shall also include a photo of each indication after each cycle with the identifying number and length measured with a ruler or tape measure and photographed after repair and magnetic particle inspection to confirm they are not cracks.

15.1.6 Retests

Following failure of a test, perform equipment rework and retest until compliance with the stated requirements is achieved.

1. If corrections or modifications are made affecting the item under test, the Contractor shall perform a complete system retest at its expense to demonstrate compliance with the Specification requirements.

2. Each individual retest must demonstrate that the entire set of prescribed criteria has been met following rework.

3. SEPTA may at its discretion waive portions of the retest.

15.1.7 Additional Tests

SEPTA reserves the right to perform at its own expense additional operating tests of each vehicle to verify the acceptability of the vehicles:

1. These additional tests will be conducted within 30 days after completion of Contractor acceptance testing.

2. The Contractor may be required to participate and furnish technical assistance for such tests.

3. If the result of the testing indicates that the vehicle was noncompliant with the Specifications (in line with the stated purpose of the testing), the vehicles in question shall be returned to the Contractor for correction, and on resubmittal SEPTA will have an additional 30 days to retest.

4. All expenses and costs incurred in the removal of vehicles from the designated delivery point for correction of defects shall be borne by the Contractor.

15.1.8 Test Classifications

The required tests are categorized as follows:

1. **Type Tests** shall be conducted to demonstrate compliance with design requirements at operating and environmental extremes, and the Specifications.

   a. These tests shall be performed on selected production components, systems, and completed vehicles, at the highest level of assembly that will allow demonstration of design compliance.

   b. Type tests are limited to the number of units needed to demonstrate design compliance, typically one or two.

2. **Routine Tests** shall be conducted to demonstrate that each unit produced operates within specified limits and is in compliance with the requirements of the Specifications.

    a. These tests shall be performed on each component, system, or vehicle included in the Contract.

    b. Routine test requirements may vary from an inspection and functional demonstration for a simple component to full dynamic tests of a vehicle.

    c. These tests are performed at ambient conditions unless a specific environmental or operating limit is necessary to demonstrate acceptable operation.

15.1.9 Test Procedures

Test results will not be accepted by the Engineer without an **approved** procedure. Prepare and submit a detailed test procedure for each test described in the Master Test Plan, and for other tests conducted by the Contractor in connection with its own Quality Assurance Program:

1. It shall be the responsibility of the Contractor's engineering department to develop procedures for the vehicle tests to be conducted.
2. Each procedure shall include a sign off block that includes the name and signature of the Contractor’s responsible engineer and the date the procedure was reviewed and approved.
3. Supplier procedures shall be approved by the Contractor prior to submittal to the Engineer.
4. For each test procedure, include the following:

    a. The number of the CDRL that will be satisfied by the test.

    b. Each Specification section number relevant to the system or component under test, including both the section within this Section 15, Testing, and those sections from which the test acceptance criteria were derived.

    c. A description of the test and its purpose

    d. A complete description of special tools, instruments, gauges, and equipment to be used.

    e. All settings and calibrations. Descriptions pertaining to test instruments, special tools, and equipment shall describe the item with the model number, a picture, the manufacturer, and units of measurement where applicable.

    f. Abbreviations list with definitions.

    g. Pass/fail criteria applied to the test(s) being conducted, clearly defined.

    h. References section identifying documents or references used as guidance for the test, such as APTA, FRA, ASTM, etc.

    i. A history of test revisions maintained and recorded within the test document, with a description of the changes.

j. Areas for recording actual values produced during the test where needed, with pass/fail criteria and associated tolerances shown in parenthesis near the space available for recording the actual value.

k. Initial Conditions section identifying positions or state of all devices, controls, and equipment.

5. Submit with each test procedure the forms to be used to record data during the test. Include the following:

   a. Step-by-step format for data reduction

   b. Formulae used in deriving the format

   c. Criteria for acceptability (quantifiable values)

   d. Justification for the criteria set forth

6. Submit each detailed test procedure minimum 30 working days before the planned date of the test to allow time for review and **approval** of the procedure.

7. Furnish to SEPTA any mechanism (software, file format, etc.) necessary to review and analyze test data furnished to SEPTA.

15.1.10 Test Reports

Within seven days after completion of each test, submit a written report of each test including copies of all test data for **approval**.

1. The Contractor’s engineering department shall be responsible for preparation of test reports.

2. Each test report shall include a sign off block that includes the name and signature of the Contractor’s responsible engineer and the date the report was reviewed and approved.

3. Supplier test reports shall be approved by the Contractor prior to submittal to the Engineer.

4. The Contractor's quality control department shall certify all test results prior to submittal.

5. Submit test reports that follow the format of the test procedure.

   a. Include the following in each test report:

      - The same identifying information required for the test procedure
      - A description of the test
      - All raw data collected in the test
      - Signature fields for individual conducting the test and witness, if applicable
      - Calibration date of test equipment used.
      - All data reduction forms
      - Summary of the results

6. In every case, the test report shall include a summary of the results in a form that can be directly compared to the Specifications without further calculations.

7. Test results shall not be accepted by the Engineer without an **approved** procedure. Supplier test reports and procedures shall be approved by the Contractor prior to submittal to the Engineer. No test will be considered completed until a test report has been received and **approved** by the Engineer.

8. Include test reports of routine tests in the appropriate Vehicle History Book, as specified in Section 20, Program Control and Quality Assurance.

15.2 Insulation Testing

When an insulation test is specified to be performed, comply with the requirements of IEEE Std 16, Section 5.9, Insulation Testing. For equipment manufactured outside the US, an alternate standard may be proposed.

15.3 Non-Destructive Testing and Inspection

Where specified in this Section, perform the following:

1. Magnetic Particle Testing: Perform in accordance with ASTM E709, using wet fluorescent particles. Inspections shall be by personnel certified to NAS 410.

2. Dye Penetrant Inspection: Perform in accordance with ASTM E165/E165M, using fluorescent dye.

15.4 Microprocessor-Based System Software Tests

Perform type testing of all system or subsystem level features and functions as required by Section 18, Systems and Software Engineering, to confirm software performance using the complete range of operating conditions and inputs.

1. Microprocessor software test procedures shall include test cases designed to uncover software errors as appropriate.

2. Submit all software type test plans for review and **approval** prior to testing.

15.5 Component Type Tests

15.5.1 General

Comply with the following:

1. Perform type tests at the manufacturer's facilities unless indicated otherwise in the Specifications.

2. All pneumatic, hydraulic (if applicable), electrical, and electronic equipment shall undergo shock and vibration testing in accordance with EN 61373.

3. Packaged components and assemblies that are not tested as parts of a system shall be tested at the point of manufacture as part of the Quality Assurance Program. Test results shall be available for the Engineer's inspection.

4. For each type of microprocessor-based control unit not tested as part of another type test, perform a functional test on one unit that simulates all normal and abnormal inputs and verifies all outputs.

5. Tests shall demonstrate that the components or set of components are likely to meet specified requirements when installed on the vehicle.

6. To the extent practical, test conditions shall replicate worst-case operating conditions of the application, such as ambient temperatures, voltage ranges, and other applicable conditions.

7. If, subsequent to **approval** of a component type test, there are changes to product, design, production process, materials, or location of manufacture, another type test shall be performed. The scope of the subsequent type test will be at the sole discretion of the Engineer.

15.5.2 Flammability, Smoke Emission, and Toxicity (FST) Type Test

Test all materials provided for the vehicle in accordance with Section 16, Materials and Workmanship, to verify compliance with the flammability and smoke emission performance requirements of Section 16.

15.5.3 Paint Performance Type Test

Test the final painted or powder coated surface on the first component of the production run in accordance with Section 16, Materials and Workmanship.

15.5.4 EMI/EMC Component Type Tests

Test each component containing electronics to verify compliance with the Specifications:

1. Testing shall be performed by a qualified test laboratory.

2. Perform tests in accordance with EN 50121-3-2.

3. Perform each individual emissions and immunity test cited in EN 50121-3-2 as applicable to the specific subsystem/component.

4. For immunity tests, develop detailed definitions of EN 50121-1 Performance Criteria A and B applicable to each individual subsystem/component and include in the respective test procedures, including signals to monitor and acceptable signal change boundaries.

15.5.5 Cab and Floor Heater Type Tests

Perform a type test demonstrating that heaters meet requirements specified in Section 7, Heating, Ventilating, and Air Conditioning.

15.5.6 Motor Type Tests

15.5.6.1 AC Traction Motor Type Test

Perform a type test in accordance with a mutually acceptable method from IEC 60349-2 to determine the characteristics and efficiency of the traction motor.

15.5.6.2 AC Auxiliary Motor Type Test

Perform an IEC 60349 type test for one of each type of ac auxiliary motor to demonstrate its capabilities and power rating:

1. Include a temperature-rise test.
2. Test each model at its continuous rating.

15.5.6.3 Low-Voltage DC Motor Type Test

Perform an IEC 60349 type test for one of each type of low-voltage dc motors to determine its capabilities and power rating.

15.5.7 Traction Gear Unit Type Test

Subject gear unit to a 100-hour test, and mount with torque load simulation. Alternatively, submit 100-hour test data and gear tooth contact verification data, previously run on identical gear units:

1. The load cycle for the 100-hour test shall consist of a maximum power motor and brake cycle repeated to simulate a typical load cycle in revenue service on the Project alignment.
2. The test shall subject the units to conditions that are more severe than would occur under the most extreme operating conditions, by increasing the torque by 20%.
3. If two motors are controlled in parallel, the torque load shall include the effects of uneven torque distribution due to wheel diameter differences, as specified in Section 10, Propulsion System and Control, in the Traction Motors section.
4. Include the following as a minimum:
    a. Check and record gear tooth mesh and tooth pattern before the test.
    b. Start the test with the unit at a temperature from 15 C to 32 C (59 F to 90 F). A fan or other device may be used so that in-service airflow conditions in driving direction are simulated.
    c. Measure temperature rise in the oil sump. Maximum temperature shall not exceed the gear oil supplier's recommendations consistent with the life between oil changes, as stated in the Contractor's maintenance manuals.
    d. Measure the bearing temperature.
    e. Reverse the direction of rotation every successive 5 hours until the 100-hour test is completed.

5. During the 100-hour test, perform noise and vibration tests to verify compliance with requirements of Section 2, Design and Performance Criteria:

   a. Take vibration and sound level readings at such intervals as necessary to verify compliance with the Specifications.

   b. Monitor for any drippage or seepage from the unit.

6. After completion of the test, perform the following:

   a. Check the oil for contamination or metal particles.

   b. Disassemble the gear unit and examine all parts.

   c. Check and record gear tooth mesh and tooth pattern.

15.5.8 Auxiliary Power System Type Tests

15.5.8.1 Auxiliary AC Inverter Type Test

Perform tests based on the type test requirements of IEC 61287-1, which shall take into account the specified design requirements, environmental ranges, and supply voltages and demonstrate that the equipment complies with the Specifications. See Section 9, Electrical Equipment.

In addition, perform a combined system test demonstrating the capability to start up all ac loads, especially the HVAC compressors, under the worst-case loading scenario possible, not including load failures.

15.5.8.2 DC LVPS and Battery Charger Type Test

Perform tests based on the type test requirements of IEC 61287-1.

1. Perform a test to demonstrate compliance with specified regulation and ripple requirements, monitor output voltage and output voltage waveforms with an oscilloscope at operating points representing the full range of conditions for delivery of rated output voltage and for routine current limit operation.

2. If more than one LVPS is used in normal operation, demonstrate equal load share and dynamic stability with both units connected during the above tests.

15.5.9 Tow Bar and Draft Gear Type Test

Comply with the following:

1. Tow bar and draft gear type tests shall include tests that validate the performance and capacities of the following:

   a. Tow bar draft and buff loading

   b. Draft gear deflection and emergency release

   c. Electrical jumper test for range of operation and functionality

d. Anchor casting static loading

e. Mechanical coupling and uncoupling

f. Centering

g. Vertical strength capability

h. Folding and stowage

2. These tests shall be performed on two completed vehicles or on a test stand as appropriate.

15.5.10 Apparatus, Hoses, Air Lines Cables Clearance Type Tests

Perform tests to confirm that all apparatus, hoses, air lines, cables, and other appurtenances do not rub against surfaces that would cause premature wear or a source of failure to the systems of the vehicle.

This test shall confirm the dynamic performance of all apparatus, hoses, air lines, cables, and other appurtenances through the dynamic range of x, y, and z directional motion using load and vibration cases that simulate worst-case operation on SEPTA.

Tests of hoses shall be conducted while at maximum allowable internal pressure and while not under pressure and be performed under static and dynamic conditions to represent worst-case conditions anticipated on SEPTA's alignment.

15.5.11 Truck Frame Type Test

15.5.11.1 General

Perform a static load test and a fatigue endurance test. Select test loads and conditions that will demonstrate conformance to the Specifications.

The load test shall be performed with the suspension elements replaced by solid blocking. A stiff elastomeric pad shall be placed between the solid blocking and the truck frame or bolster to allow deflection without altering the normal load path.

Testing shall include the truck in its entirety with all sub-components including the bolster, frame in isolation (without bolster), and the bolster only.

15.5.11.2 Test Set Up

Set up the static load and fatigue tests as follows:

1. Apply minimum 75 rosette strain gauges to the truck frame and bolster at locations of expected high stress and other areas of interest:

    a. Type: SR-4 or other **approved** strain gauges specifically suitable for the application.

    b. Location: Based on the stress analysis and the Contractor's experience, subject to the direction of the Owner.

    c. Calibration: In accordance with manufacturer's instructions for material being measured.

d. Temperature compensation: Apply to the gauges.

2. Use a load cell at each point of load application.

3. Use deflection gauges during the static load test to monitor vertical and lateral deflection of the truck frame.

15.5.11.3 Static Load Test

Perform truck frame overload test to verify truck can withstand maximum static load with a safety factor. Overload case shall be maximum allowable load plus 20%.

Test Unit: The test truck shall be identical to the production truck.

Test Purpose:

1. To verify that the maximum allowable static stresses selected by the Contractor are not exceeded under the maximum expected static loads.

2. To verify the predictions of the finite element analysis.

3. To simulate as closely as possible the actual loading conditions to which the truck will be subjected in service, by using appropriate methods and points of test load application and reaction.

Pre-Test Non-Destructive Testing:

1. Perform a magnetic particle test or dye penetrant inspection on the test unit for cracks and other defects that might impair the performance of the truck during the test.

2. Perform test or inspection in accordance with the Non-Destructive Testing and Inspection section, above.

3. Inspection shall be performed at the test laboratory; final inspection results at the production facility may not be substituted.

4. Record the defects found, and if required, repair using an **approved** procedure.

5. Document the type, size, location, and repair of each defect by photographs and drawings.

Test Steps:

1. The load cases to be tested shall include the following:

   a. The combined static loads

   b. The fatigue test load case shall be tested statically, including all phasing arrangements that will be used applied simultaneously.

   c. Maximum load test to 120% of design load.

2. For each load test, load the truck and bolster twice, with complete release of the load between applications.

3. For the static loads, apply test loads as follows:

    a. Vertical load: The truck's share of completed vehicle weight plus an AW4 passenger load minus the weight of the truck.

    b. Lateral load: Load developed at vehicle overturning.

    c. Longitudinal load: The maximum possible instantaneous braking effort (friction and dynamic plus track brake) and 50% adhesion at the wheels at AW4 load.

    d. Lateral and longitudinal loads shall act as if they were applied at the center of gravity of the completed vehicle plus an AW4 passenger load.

    e. Accessory loads, such as brake units, track brakes, and traction motors shall represent maximum steady state conditions. For example, maximum motor torque and brake unit weight, and maximum brake unit reaction and motor weight.

    f. All loads shall be applied to produce the worst stress conditions on the truck.

4. If non-US standards were used for the design of the truck frame and bolster, the Contractor can propose using the non-US standard's test regimen with the **approval** of the Engineer.

Measurements During Test:

1. Re-zero strain gauges after the first load application and record and report the offset from zero.

2. Take all required data during all load applications.

3. Record all load cells simultaneously with all strain gauges.

Test Results:

1. The truck will be compliant with the Specifications if all of the following are met for the static combined load application:

    a. Maximum stresses calculated from strain readings in any gauge during the second load application do not exceed 50% of the material's yield stress.

    b. Indicated residual strains following removal of the second loading do not exceed the maximum error resulting from the accuracy of the instrumentation.

    c. There are no permanent deformations, fractures, cracks, or separations in the truck.

2. If any of the above criteria are not met, the truck design shall be corrected and the truck retested at the Contractor's expense, and this process shall continue until these criteria are met.

Test Unit Disposal: The test unit shall not subsequently be used on a production vehicle, and shall be permanently marked as a test unit and may be used as a training aide, if feasible, or otherwise destroyed.

15.5.11.4 Fatigue Test

Test Purpose: To demonstrate that the truck has adequate fatigue strength under dynamic loading.

Pre-Test Non-Destructive Testing:

1. Perform a magnetic particle test or dye penetrant inspection on the test unit for cracks and other defects that might impair the performance of the truck during the test.
2. Perform test or inspection in accordance with the Non-Destructive Testing and Inspection section, above.
3. Record the defects found, and if required, repair using an **approved** procedure.
4. Document the type, size, location, and repair of each defect by photographs and drawings.

Test Steps:

1. Base fatigue test: Subject the truck frame and bolster to a base test of a minimum 4 million cycles of dynamic loading.
2. Extended fatigue test: Upon successful completion of the base fatigue test, subject the truck to an extended fatigue test where the truck is tested for two additional increments. Each increment shall be 1 million cycles, with loads increased to 110% of the base test for the first increment and increased to 120% of the base test for the second increment, or as **approved**.
   a. This testing shall continue until truck failure or until the additional 2 million cycles are completed, whichever occurs first.
   b. The additional 2 million cycles above the base cycles are solely to determine fatigue life margin.
3. Apply the following loads in accordance with the Fatigue Design section in Section 11, Truck Assemblies, except that loads shall be based on the completed vehicle:
   a. Vertical load
   b. Lateral load
   c. Longitudinal load
   d. Accessory loads
4. Select the phasing of the loads such as to produce the worst-case stresses at critical locations.
5. During fatigue tests, continuously monitor and record at least 10 selected strain gauges from the static test and all load cells for both maximum and minimum loadings and phasing to ensure loads are accurately applied during the test.
6. If non-US standards were used for the design of the truck frame and bolster, the Contractor can propose using the non-US standard's test regimen with the **approval** of the Engineer.

Post-Test Non-Destructive Testing:

1. At the conclusion of the base 4 million cycling and again after each extended cycling increment, perform a magnetic particle or dye penetrant inspection for cracks.
2. The post-test inspection procedure shall duplicate the pre-test inspection procedure.

Test Results:

1. The truck will be compliant with the Specifications if all of the following are met after 4 million cycles:
   a. Stresses calculated from strains measured at critical locations do not exceed Contractor-selected fatigue allowables included in the test procedure.
   b. This stress range shall be within the allowable fatigue endurance limit for non-redundant structures obtained from one of the following:
      - AAR M-1001 (AAR MSRP Section C-II), Section 7.4, Material Properties – Fatigue Properties of Members and Details;
      - AWS D1.1/D1.1M; or
      - The Contractor's own tests if more appropriate and conservative.
   c. Following removal of all loads, indicated residual strains at strain gauges on principal structural elements do not exceed the maximum error resulting from the accuracy of the instrumentation.
   d. There are no permanent deformations, fractures, cracks, or separations in the truck.
2. If cracks are found during the base cycle testing that were not present before the test, or cracks have propagated from original recorded dimensions, correct the design and rerun the test from the beginning with a new test specimen.
3. Redesign and retest shall continue until these criteria are met.

Test Unit Disposal: The truck and bolster that undergo this test shall not subsequently be used on a production vehicle and shall be permanently marked as a test unit and may be used as a training aide, if feasible, or otherwise destroyed.

15.5.12 Wheel Equalization Type Test

Perform a type test on a production unit of each truck type demonstrating that the truck complies with requirements in Section 11, Truck Assemblies, for equalization. The truck may be artificially loaded.

15.5.13 Pantograph Type Test

Perform pantograph type tests on a production unit based on the type test requirements of IEC 60494-2.

15.5.14 Traction Inverter Type Test

Perform traction inverter type tests on a production unit, based on the type test requirements of IEC 61287-1. These tests shall confirm compliance with all aspects of the specified design requirements, environmental ranges, and supply voltages of Section 9, Electrical Equipment, and Section 10, Propulsion System and Controls.

15.5.15 Not Used

15.5.16 Dynamic Brake Resistor Type Test

Perform type tests demonstrating compliance with the requirements for dynamic brake resistors in Section 10, Propulsion System and Control.

15.5.17 Inductor Type Test

Perform type tests demonstrating compliance with the requirements for inductors in Section 9, Electrical Equipment.

15.5.18 Door Operator Type Test

Perform a type test defined by the manufacturer on the passenger door operator and associated controls demonstrating that the operator and controls comply with the requirements in Section 6, Passenger Doors.

At a minimum, the door operator type test shall include testing of the operator for 500,000 cycles.

15.6 Vehicle-Shell Structural Type Tests

15.6.1 General

Demonstrate that the critical portions of the vehicle-body structure comply with the Specifications and ASME RT-1.

1. Demonstrate that under the loads specified in Section 3, Vehicle-Body Structure, the criteria have been met and there is no loss in form, fit, or function of the structure. There shall be no permanent deformation anywhere. There shall be no distortion of surfaces of members.

2. The test shall meet the ASME RT-1 test criteria.

3. The test shall validate the FEA model globally to ensure that the load paths are accurately captured in the model within 75% accuracy.

    a. For areas with stresses greater than 75% of the allowable, the accuracy of the global model shall be increased to match the margin.

    b. For areas of local concentrations, the global load path shall be ensured to verify the input to the local analyses. The proposal of validation method shall be included in the Vehicle-Body Stress Analysis and Tests Plan specified in Section 3.

15.6.2 Test Setup

15.6.2.1 General

The Contractor's test setup and test execution shall comply with ASME RT-1 requirements for Proof Load Tests and the **approved** test procedure.

1. At a minimum, the procedures shall describe the following:

    a. The general test setup, fixtures, tooling, and method of loading.

    b. All load application points including dimensions for the position and distribution of loads, where appropriate.

    c. Details of the supports and boundary conditions.

    d. Load cell, gauge locations, including locational dimensioning of gauges.

2. The Contractor and the Engineer shall reach agreement on a number of strain and deflection gauges (rosettes) and type of rosettes and the placement of the rosettes. The minimum quantities and types of strain and deflection gauges to be used are specified below. If agreement cannot be reached, an independent third party shall be engaged to determine the number and location of gauges to be applied for this test.

15.6.2.2 Strain Gauges

Apply calibrated strain (rosettes) gauges to the vehicle structure:

1. Quantity:

    a. Vertical load tests: Minimum 300

    b. End-compression load tests: Minimum 300

    c. Collision and corner post load tests: Minimum 100

    d. Diagonal jacking tests: Minimum 300

2. Type:

    a. Rosette, bonded resistance, SR-4; or other **approved** gauges suitable for the application.

    b. Linear gauges may be used instead of rosettes where it can be shown that the stress is in one direction only and that direction has been identified.

    c. Gauges used on FRP shall be appropriate for that material.

3. Location:

    a. Based on the Contractor's experience, the stress analysis, and the Engineer's recommendations.

    b. Place half the gauges in areas where the stress may be critical and the other half in locations to validate the stress analysis.

   c. Gauges may be used for more than one test if located on the structure appropriate to more than one test, but the required number of readings shall be taken for each test.

4. Calibration and temperature compensation: In accordance with manufacturer's instructions for material being measured.

15.6.2.3 Deflection Gauges

Apply calibrated deflection gauges to the vehicle structure:

1. Quantity:
   a. For each section, five gauges to measure the side sill vertical deflection, except for the post test on the cab section shall have these gauges.
   b. At both ends of the vehicle shell, two gauges total, one at each side sill corner to measure longitudinal deflection.
   c. Between each section, four gauges total, one at each corner to measure longitudinal deflections.
   d. For each section, four gauges total, one at each corner on the side sills to measure transverse deflections.
   e. For the collision and corner post load tests, additional gauges to measure the longitudinal deflection of the posts at five locations on the post.
   f. For the diagonal jacking test, additional gauges to measure the vertical deflection at the jacking pads.
2. Type: Displacement transducers with enough stroke to measure 1.25 times the deflection predicted by the FEA.
3. Measurements: Shall be taken to the nearest 0.25 mm (0.01 in).
4. Location:
   a. As noted above.
   b. Based on the Contractor's experience, the stress analysis, the Engineer's recommendations, and verification that the loading condition remains safe.
5. Calibration and temperature compensation: In accordance with manufacturer's instructions.

15.6.2.4 Load Cells

Apply calibrated load cells:

1. Quantity: Sufficient to measure the input load and the reaction loads.
2. Type: Load range of 1.25 times the applied load or expected reaction load.
3. Location: At all load and reaction points.

4. Calibration and temperature compensation: In accordance with manufacturer's instructions.

15.6.3 Vertical Load Test

Test Purpose: To confirm the ability of the vehicle-body structure and articulation joints to resist the static and fatigue loads specified in Section 3, Vehicle-Body Structure, Vertical Design Load Strength Requirements section.

Test Setup: Comply with the **approved** test procedure.

Test Load: See Vertical Design Load Strength Requirements section in Section 3, Vehicle-Body Structure.

Test Steps:

1. Apply test load to the specimen in four increments:
    a. Increment one: Equal to the complete, ready-to-run vehicle-body weight (complete vehicle minus trucks).
    b. Increment two: Add load such that total load is equal to AW2 passenger load.
    c. Increment three: Add load such that total load is equal to AW3 passenger load.
    d. Increment four: Add load such that total load is equal to AW4 passenger load.
2. Unload the specimen in the same increments that it was loaded, in reverse order.
3. Door operation during test:
    a. At each increment of test load, open and close doors electrically by means of the door operators.
    b. In case of failure to operate at the prescribed speed or any indication of binding, take corrective action to the vehicle structure, or door arrangement, and repeat the vertical load test in its entirety.
4. Bridge plate operation during test:
    a. At each increment of test load, extend and retract bridge plate electrically by means of the bridge plate operators.
    b. In case of failure to operate at the prescribed speed or any indication of binding, take corrective action to the vehicle structure or bridge plate, and repeat the vertical load test in its entirety.

Measurements During Test:

1. Measure and record vehicle-body vertical and longitudinal deflection, load cell readings, strains, and flatness of side skin on the vehicle-body shell with each test load applied:
    a. Plot vertical deflections to verify linearity.
    b. Plot 10 highest strain values to verify linearity.

   c. Visually inspect for deformation.

2. Measure and record the opening and closing time of each door leaf.

3. Measure and record the extend and retract time of bridge plate.

Test Results: The vehicle will comply with the Specifications if results comply with ASME RT-1 Test Criteria and **approved** test procedure criteria for this test with the following exceptions and additions:

1. Referenced loads are in accordance with Section 3, Vehicle-Body Structure.

2. Vertical deflection: Variance not more than +/- 5%.

3. Strain readings: Variance not more than +/- 5%.

4. Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses **approved** as part of the stress analysis before starting the test program.

5. Vehicle-body side sill deflection is maximum 9 mm (0.4 in) under a load equal to the passenger load of AW4, as measured from the datum line drawn from the transverse center line of the vehicle-body bolster at the truck through the transverse centerline of the articulation joint.

6. Vehicle-body vertical and longitudinal deflections measured at the side sill during the test at AW2, AW3, and AW4 agree with the analysis calculated deflection within +/- 10%.

7. The side doors open and close at all test loads at speeds and operating force levels as required without binding.

8. The bridge plate extends and retracts at all test loads at speeds and operating force levels as required without binding.

15.6.4 Compression Load Test

Confirm the ability of the vehicle-body structure and articulation joints to resist the compression loads specified in Section 3, Vehicle-Body Structure, in the End Sill Compression Load section, **Test Setup:** In accordance with ASME RT-1 and the **approved** test procedure.

Test Load: See End Sill Compression Load section in Section 3, Vehicle-Body Structure.

Test Steps:

1. In accordance with ASME RT-1 and the **approved** test procedure, with the following exceptions:

   a. Apply the load in increments of 25, 50, 75, 87.5, and 100% of specified full load.

   b. Reduce the load to maximum 2% of full load after each step, but not less than necessary to hold the test article firmly in the fixture.

Measurements During Test:

1. Measure applied and reaction forces using an independent load cell.

2. Take strain gauge and deflection readings at each load increment and at each relaxation of load.

Test Results: The vehicle will comply with the Specifications if all of the following are met:

1. The vertical deflection of each side of the test structure is within +/- 10% of the value determined by the analysis.

2. Vertical deflection readings plotted against load do not vary by more than +/- 5% from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other at the point that represents the measured deflection at maximum load.

3. Strain readings plotted against load do not vary by more than +/- 5% from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other at the point that represents the measured deflection at maximum load.

4. Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses **approved** as part of the stress analysis before starting the test program.

5. Following removal of the maximum test load:

   a. Residual vertical deflection between bolsters does not exceed 1.0 mm (0.04 in).

   b. Residual horizontal deflection between ends does not exceed 1.0 mm (0.04 in).

   c. Indicated residual strains at strain gauges on principal structural elements do not exceed the maximum error resulting from the accuracy of the instrumentation.

6. There are no permanent deformations, fractures, cracks, or separations in the vehicle structure or in the vehicle-body sheathing.

15.6.5 Collision Post and Corner Post Load Tests

Confirm the ability of the collision posts, corner posts, and associated supporting structures to resist the elastic design loads specified in ASME RT-1 Table 2, Structural Load Requirements for Streetcars.

The vehicle will comply with the Specifications if all of the following are met:

1. Deflection readings plotted against load do not vary by more than +/- 5% from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point which represents the measured deflection at maximum load.

2. Strain readings plotted against load do not vary by more than +/- 5% from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other near the point which represents the measured deflection at maximum load.

3. Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses **approved** as part of the stress analysis.

4. Indicated residual strains at strain gauges on principal structural elements following removal of the maximum loading do not exceed 50 microinch/in.

5. There is no permanent deformation, fractures, cracks, or separations in the vehicle structure.

Broken welds shall be jointly inspected by the Contractor and the Engineer to determine if the failure is the result of weld quality or stress.

15.6.6 Crash Energy Management (CEM) Tests

Conduct CEM tests in accordance with the recommendations of ASME RT-1, Section 10.4, Crash Energy Management Tests, and as agreed by the Engineer to validate the CEM design and verify the Crashworthiness Analysis simulations of Section 3, Vehicle-Body Structure.

Include the CEM testing plan, or waiver justifications, as part of the CEM and Collision Survivability Plan CDRL, specified in Section 3.

15.6.7 Diagonal Jacking Test

Conduct diagonal jacking tests to confirm that the vehicle can maintain structural integrity during a diagonal jacking load case.

Test Setup:

1. Load the vehicle shell to its AW0 weight.
2. Hang trucks (or an equivalent weight) from the body bolsters.
3. Support the vehicle shell symmetrically at the minimum number of jack pads and placement necessary to support the vehicle safely.

Test Steps:

1. Lower the jack that, when lowered, subjects the vehicle-body structure to worst-case diagonal loading.
2. Lower in five equal increments until the load on the jack is 10% of its original value.
3. Reverse the procedure until the load on the jack is returned to its original level.
4. Repeat the test using the vehicle jack socket adapters.

Measurements During Test: Record all gauge and load cell readings at each increment of jack position.

Test Results: The vehicle will comply with the Specifications if all of the following are met:

1. Maximum stresses calculated from strain readings in any structural element do not exceed the allowable stresses **approved** as part of the stress analysis before the start of the test program.
2. Strain readings plotted against load do not vary by more than +/- 5% from a straight line (linear) deflection curve, with one end point at the origin (no load) and the other at the point that represents the measured deflection at maximum load.
3. The vertical deflection of each side of the test structure is within +/- 10% of the value determined by the analysis.

4. Following return to original level, indicated residual strains at strain gauges do not exceed the maximum error resulting from the accuracy of the instrumentation.

5. There are no permanent deformations, fractures, cracks, or separations in the vehicle structure.

15.6.8 Validation of Linear Elastic Analysis

15.6.8.1 Measured vs. Analytical Values in Test Procedures and Test Reports

Test Procedures and Test Reports:

1. See the Contract Deliverables Requirements List (CDRL) section, below.

2. Test Procedures: For analytical strain (or stress) values at selected strain gauge locations, not less than 50% of the total gauges, insert values obtained from the stress analyses required in Section 3, Vehicle-Body Structure.

Test Reports: For test report tables that require calculated percent difference between analytical and measured values, it is defined as follows:

$$\text{Percent Difference } = \frac{Measured\ -\ Analytical}{Measured} \times 100$$

where

Measured = the value obtained from strain gauges or other instruments during testing
Analytical = the value obtained through calculation, as specified in Section 3

15.6.8.2 Results

The percent difference between the measured and analytical values shall be as follows:

1. Minimum 75% of selected measurements recorded: Within 15%.

2. Remaining 25% of selected measurements recorded:

   a. Percent difference more than 15%, and measured value greater than or equal to 35% of yield strength of material: Prepare a detailed explanation of the reasons for the excessive variance.

   b. Percent difference not within the above-specified tolerance:

      - Revise the stress analyses, update the finite element model, and re-run all FEAs (see Section 3, Vehicle-Body Structure).

      - Repeat the process until the percent difference is within the specified tolerance.

      - Recalculate all manual analyses using data from the finite element analysis using the corrected values.

      - Revise and resubmit the stress analysis report in accordance with Section 3.

- All results from re-analysis shall meet the requirements of the Specifications and, if they do not, the design shall be corrected.

15.7 System Type Tests

15.7.1 General

The following system type tests shall be performed by the Contractor, or under its direction, to demonstrate conformance to the requirements of the Specifications.

15.7.2 System-Level Functional Type Tests

For each system that includes software, perform a functional test of hardware and software to verify correct operation before the system is integrated into the vehicle.

15.7.3 Floor and Roof Assembly Fire Performance Type Test

Test the floor and roof assemblies (structural):

1. Test Setup: In accordance with NFPA 130 Section 8.5, Fire Performance
2. Test Steps: In accordance with ASTM E119
3. Fire Exposure Duration: In accordance with NFPA 130, Section 8.5, Fire Performance
4. Test Results: In accordance with NFPA 130 Section 8.5, Fire Performance

15.7.4 Propulsion Combined Type Test

Perform a laboratory test on one truck set of propulsion equipment to demonstrate that the propulsion system functions properly and meets specified requirements for performance and conductive emissions before installation on the vehicle.

1. **Scope:** Include motors, inverter, brake resistor, protection devices (i.e., HSCB), logic, controls, master controller, and other equipment as appropriate.
2. **Test Setup:**
   a. The physical layout of vehicle components and cabling for this test shall simulate actual vehicle conditions as much as possible and shall be **approved**.
   b. Simulate vehicle inertia with a dynamometer that uses flywheels or programming of a motor generator.
   c. Simulate vehicle resistance by means of a motor-generator.
   d. Simulate vehicle wash mode activation.
3. **Test Results:**
   a. Demonstrate that the propulsion functions properly and meets specified requirements before installation on the vehicle.

b. Demonstrate compliance with the conductive emission requirements in Section 2, Design and Performance Criteria.

c. Demonstrate compliance with the requirements for vehicle wash mode specified in Section 10, Propulsion System and Control.

15.7.5 Friction Brake System Type Test

Perform a type test on the complete friction brake system and all components:

1. These tests may be included with the propulsion system laboratory tests.
2. Use a dynamometer to confirm braking capability, thermal capacity, response, and wear rates.
3. Testing shall include hot and cold retardation, wet and dry retardation, actuation energy storage, and control response.
4. Perform a test to confirm redundancy of the friction brake system.

15.7.6 Auxiliary Power System Type Test

Perform simulated tests of interaction between vehicle equipment and auxiliary ac inverter and LVPS to demonstrate compliance with the requirements of Section 9, Electrical Equipment.

Perform a load shed test to confirm the auxiliary power system performance in in compliance with the requirements of Section 9, Electrical Equipment.

15.7.7 Truck Assembly Type Test

15.7.7.1 Wheel Equalization

Perform a type test on a production unit of each truck type demonstrating that the truck complies with requirements in Section 11, Truck Assemblies, for equalization. The truck may be artificially loaded.

15.7.7.2 Primary Suspension System

Perform primary suspension test during the same time period as the static and fatigue test.

1. Perform a load deflection test in the new condition and after an accelerated aging test to demonstrate that the spring rate of the primary suspension system stays within the design limits. Perform a static creep test of sufficient duration to estimate creep after 10 years.
2. The purpose of these tests shall be to demonstrate that the primary suspension system performance meets the design requirements and will not produce excessive deflections under any service load or allow the truck to infringe on the minimum clearance to the top of the rail as specified in Section 11, Truck Assemblies.

15.7.7.3 Secondary Suspension and Load Leveling System

Perform type testing on one set of secondary suspension and load leveling equipment, including all associated sensors and controls, to demonstrate that the secondary suspension system performance meets the design requirements specified in Section 11, Truck Assemblies.

Life cycle testing shall confirm that the equipment will function reliably over the life of the vehicle.

15.7.8 Door System Type Test

Perform a type test on one door of each type before installing on the vehicle, including door operator, control, and sensitive edge:

1. Door shall be assembled as a unit for the test.
2. The test fixture used shall accurately represent the actual vehicle body and installation.
3. Include an accelerated life test of 1.5 million cycles for one complete set of door equipment, monitoring the operation, functions, and performance to demonstrate compliance with specified requirements including operation of interior and exterior emergency release devices every 5,000 cycles.

15.7.9 Bridge Plate System Type Test

Comply with the following, in addition to requirements for the Door System Type Test, above:

1. Perform a type test on one bridge plate and bridge plate operator, and controls.
2. Door and bridge plate equipment shall be assembled as a unit for the test.
3. In addition to the accelerated life test of doors, include 250,000 cycles for the bridge plate equipment.
4. Testing shall include tests to confirm compliance with design requirements in a climate chamber simulating worst-case climatic conditions, including the introduction of contaminants. See Section 6, Passenger Doors.

15.7.10 Unitized HVAC System Type Test

15.7.10.1 General

Perform a type test on one self-contained HVAC unit of each type, complete with all controls:

1. Testing shall be performed in a climate room that is a temperature-controlled facility suitable for the range of specified tests.
2. The test shall confirm airflow, vehicle internal pressure, water elimination, heating capacity, cooling capacity, controls, extreme operating conditions, unit noise, vibration isolation and performance under typical vehicle vibration conditions, and power consumption. Submit test plan as part of the system design development process.

3. Perform a dirty filter simulation test to confirm system performance with the filter at less than 5% remaining usable capacity.

4. Perform a unit structural test to confirm structural performance to support 136 kg (300 lb) worker walking on the unit.

5. Perform test to confirm performance of compressor high/low pressure cutout function.

6. Perform restricted ai flow heating test to confirm heating capacity with overheat heat cutout.

7. Perform condenser fan motor test to confirm motor performance throughout motor temperature range limits.

8. Smoke detector test to confirm specification and design requirements are met as specified in Section 7, HVAC.

9. Test setup shall be according to ANSI/ASHRAE Standard 37, including instrumentation accuracy and tolerances requirements.

10. Record all data required by ANSI/ASHRAE Standard 37 using an appropriate data acquisition system.

11. Perform the test to simulate the vehicle wash mode activation and demonstrate automatic deactivation of ventilation fans to avoid moisture/water ingress.

15.7.10.2 Airflow Test

Test Conditions:

1. Ambient room temperature of 20° C (68° F).

2. Interior room temperature of 20° C (68° F).

3. "Dry" evaporator coil.

Test Steps:

1. Adjust the fresh airflow to comply with the requirements of Section 7, Heating, Ventilating, and Air Conditioning.

2. Adjust the return airflow such that total airflow is in accordance with the required design value.

Measurements During the Test:

1. Use the flow measurement device described in ANSI/ASHRAE Standard 37 and related standards for measurements of the total/supply air.

2. Use the flow-hood type instrument for measurements of the fresh air.

Test Results: The fresh airflow and total airflow shall comply with the requirements of Section 7 and manufacturer's design parameters.

15.7.10.3 Scan Test

Test Conditions:

1. Expose temperature control components to the temperature environments they will experience on the vehicle.
2. Test requirement for maximum exterior side wall temperature is 52° C (125° F).
3. The use of test switches or potentiometers to control the unit independent of the temperature sensors is prohibited.

Test Steps:

1. Simulate actual operation to the extent possible by slowly varying the temperature in the test rooms, as appropriate for the control system, to reflect natural temperature lags.
2. Cycle the simulated vehicle interior and ambient temperatures through the operating range of the temperature sensors.
3. Verify all points of temperature control on temperature rising and temperature falling.

Measurements During the Test:

1. Instrument the simulated vehicle interior and ambient rooms with temperature measuring devices to determine when various control switching points are reached.
2. Connect the contactor coils to the event recorder or other suitable recording instrumentation to determine which contactors are picked up to verify control response.

Test Results: Malfunction of the system or components at any temperature constitutes a failure of the test.

15.7.10.4 Control Stability Test

Comply with the following testing requirements:

1. Under steady state operation at design conditions, vary the LVPS voltage between the limits allowed by Section 9, Electrical Equipment, to show the effect of such change.
2. Shut down and restart the system while the control voltage is at its minimum value.

15.7.10.5 Cooling Capacity

Verify cooling capacity at the design criteria conditions specified in Section 7, Heating, Ventilating, and Air Conditioning, using the methodology of ANSI/ASHRAE Standard 37:

1. In addition to test "A", select one of the secondary applicable test methods "B" from Table 1 of the Standard.

2. Verify the efficiency of the unit's mixed air plenum design:

    a. Perform the cooling capacity verification test using the normal multi-streamed airflow configuration with the outside air (fresh air) intakes open to the design exterior ambient air condition and the return air stream open to the design interior air condition, balanced to achieve the design air proportions.

    b. Significant degradation of performance shall not be present when operating in this actual configuration.

    c. Verify and finalize the design of the mixing plenum before proceeding with the remaining sections of the unit type test.

    d. Record the data, after conditions are stabilized, in 10-minute intervals for 1 hour.

15.7.10.6 Maximum Operating Conditions

Perform a system functional test as follows:

1. Test Conditions:

    a. Conduct test with the following temperatures:

        - Ambient condition: DB and WB Maximum Operating Conditions temperatures, as found in Section 7, Heating, Ventilating, and Air Conditioning, in the Cooling Design Criteria section.

        - Recirculated air to evaporator: 24° C (75° F) DB and 60% relative humidity.

    b. Conduct test at nominal supply voltage.

2. Test Steps:

    a. Operate the unit under the conditions above.

    b. At the end of 1 hour of operation, momentarily stop the system and then restart.

    c. The system shall continue to function properly with all components safe from malfunction. There is no capacity to be met.

3. Measurements During Test:

    a. Record all data every 5 minutes during steady state operation.

    b. Record each condenser motor's temperature rise during the test and verify that it is within the motor manufacturer's motor-winding insulation and heat rise and overheat-protection design ratings.

4. Test Results:

    a. Successful test: Continuous operation of the system at these conditions for 1 hour without shutdown due to high pressure, modulation, circuit breaker trip, compressor motor overload, or any device failure.

b. Test Failure: A shutdown or capacity modulation for any reason while operating at these conditions.

15.7.10.7 Modulation Pressure Switch Test

Demonstrate capacity modulation capability as follows:

1. Test Conditions: Perform the test at ambient temperatures above Maximum Operating Conditions, as specified in Section 7, Heating, Ventilating, and Air Conditioning, in the Cooling Design Criteria section.

2. Test Steps: As the condenser outlet air dry bulb temperature rises, allow the system to cycle by pressure transducer or modulation pressure switch.

3. Measurements During Test:

   a. Record the frequency of pressure switch cycling.

   b. Record all system pressures and temperatures.

4. Test Results: A successful test consists of 1 hour of continuous operation of the system without shutdown due to high pressure, cutoff, circuit breaker tripping, compressor motor overload, or any device malfunction.

15.7.10.8 High-Pressure Cut-Off Switch Test

Test Steps:

1. Upon conclusion of the modulation-pressure switch test, slowly increase the condenser air temperature above the Maximum Operating Conditions DB temperature, as specified in Section 7, in the Cooling Design Criteria section, to achieve a discharge pressure slightly below the high-pressure switch trip point.

2. The system shall operate minimum 1 hour continuously at this condition without operation of the high-pressure cut-off device, while maintaining the interior mixture conditions defined in the section above, Maximum Operating Conditions.

3. Following this, slowly raise the condenser/fresh air ambient to the point when the high-pressure cutoff switch activates and shuts off the system.

4. Repeat this test four times.

Measurements During Test: Record pressures and temperatures of the pressure-switch cutoff and reset conditions.

15.7.10.9 Low-Temperature Operation Test

Test Conditions: Perform the test at air temperature entering evaporator coil based on the following mixture:

1. Recirculated air at 22° C (72° F) DB and 50% relative humidity.

2. Ambient conditions determined from the control chart to be 1° C (1.8° F) higher than the compressor lock-out point.

Test Steps: After attainment of the specified temperature conditions, operate the unit continuously for a period of 4 hours.

Measurements During Test: Record the data every 10 minutes (or more frequently) during steady state operation.

Test Results: During the test, the unitized air-cooling system shall operate without damage to the equipment and without the formation of ice or frost on the evaporator coil or piping.

15.7.10.10 Insulation Efficiency and Condensate Carry-Over Test

Test Conditions: Ambient and evaporator entering air temperature at 27° C (81° F) DB, 24° C (75° F) WB.

Test Steps:

1. Operate the unit continuously for a period of 4 hours at the specified conditions.
2. Verify that the condensate drains function properly.

Test Results: During the test, there shall not be condensate carry-over downstream of the condensate collection system.

15.7.10.11 Refrigerant Sample Test

Have a sample of refrigerant analyzed for contaminants by an **approved** laboratory in accordance with AHRI Standard 700:

1. The sample shall be taken from the air conditioning system of the tested unit.
2. Maximum allowable levels of contaminants shall comply with AHRI Standard 700 with the following exceptions:
    a. Moisture level of up to 45 ppm maximum.
    b. High boiling residue: Maximum 5%.

15.7.10.12 Abnormal Heating Condition, Restricted Air

Test Conditions: Maintain ambient temperature at approximately 21° C (70° F) with the following conditions:

1. System heaters activated independent of the thermostat.
2. Air conditioning compressor not operating.
3. Airflow switch bypassed.

Test Steps:

1. Slowly restrict the mixed air inlet so that heater unit temperature rises 1° C (2° F) per minute (not faster) until the high-limit switch cycles off.

2. Ease the restriction to the point where the high-limit switch remains closed.

3. Continue the heating test to simulate a dirty filter condition.

4. Operate the system until a steady condition is reached.

Test Results: The test is considered successful if the following criteria are met:

1. The back-up protection did not activate during the test.

2. The temperature inside the unit did not cause damage to the equipment and components.

3. There was an absence of smoke and odors.

4. The high-limit switch opened at the design set point +/- 6° C (11° F).

15.7.10.13 Abnormal Heating Condition, No Air

Test Conditions:

1. Maintain ambient temperature at approximately 21° C (70° F).

2. The air conditioning compressor shall not be operating, and the airflow switch shall be bypassed.

Test Steps:

1. Apply power to the heaters with no air blowing over the heaters.

2. The system shall operate as the high-limit switch cycles.

Test Results: The test is considered successful if the following criteria are met:

1. The back-up protection did not activate during the test.

2. The temperature inside the unit did not cause damage to the equipment and components.

3. There was an absence of smoke and odors.

4. The high-limit switch opened at the design set point +/- 6° C (11° F)

15.7.11 Floor Heat System Type Test

Perform a type test on the floor heat system with control system:

1. The test shall confirm heating capacity, controls, extreme operating conditions and performance under typical vehicle operating conditions, and power consumption. Submit test plan as part of the system design development process.

2. Test shall confirm that surface temperature of the heater grills at all locations do not exceed specified temperature limits.

3. Test shall confirm maximum exterior side wall temperature is 52° C (125° F).

15.7.12 Cab Controls System Type Test

Perform a type test of all elements of the cab including all switches, control levers, gauges, dials, lights and other human machine interface points to confirm compliance with design requirements as specified in Section 5, Operator's Cab Controls.

Testing shall also be performed to confirm cab controls comply with specified ergonometric design requirements as specified in Section 5, Operator's Cab Controls.

15.7.13 Communication Systems Type Test

15.7.13.1 General

Before shipping the first vehicle's communication equipment, perform a functional laboratory test:

1. The test shall include one complete vehicle set of the equipment specified in Section 13, Vehicle Communication Systems.

2. The testing shall verify compliance with the Specifications and design.

3. The testing shall include verification of cybersecurity requirements specified in Section 17, Controls, Networks, and MDS.

15.7.13.2 Fault Monitoring and Train Operator Displays (MDS TOD's)

Perform testing to validate that operation and fault indications required to be displayed as part of Section 17, Controls, Networks, and MDS, are operating as intended.

15.7.13.3 Intercoms

15.7.13.3.1 Cab Intercom to Passenger Intercom

Testing shall validate proper communication between the cab intercom and passenger emergency intercoms as indicated in Section 13, Vehicle Communication Systems.

15.7.13.3.2 Cab Intercom to Public Address System

Testing shall validate the ability to make ad-hoc announcements from the cab intercom into the public address system as specified in Section 13, Vehicle Communication Systems.

15.7.13.3.3 Cab to Cab Intercom

Testing shall validate proper communication between cab intercoms as specified in Section 13.

15.7.13.4 CCTV

15.7.13.4.1 Nominal Recording Test

Validate CCTV recording as per Section 13, Vehicle Communication Systems.

15.7.13.4.2 Interior View CCTV Cab Display Screen

Default Camera Views: Validate default camera views on cab CCTV display screens as per Section 13.

Door Open Camera Views: Validate door open CCTV camera views on cab CCTV display screens as per Section 13.

Train Stopped Passenger Emergency Intercom: Validate CCTV trigger to CCTV Cab Monitor when train is stopped with passenger emergency intercom active as per Section 13.

15.7.13.4.3 Exterior Side View CCTV Display Screens

Default Camera Views: Validate default exterior camera views on cab CCTV display screens as per Section 13.

Door Open Camera Views: Validate required camera views on cab CCTV display screens as per Section 13.

15.7.13.5 Voice Radio

Test voice radio operation including the following:

1. Visual inspection of wiring and grounding
2. RF Radio Sweep of GCRTA alignment
3. Radio fault monitoring interfaces with MDS

15.7.13.6 Automatic Passenger Information System (APIS)

15.7.13.6.1 Operator Sign-In and Route Selection

Validate that Operator login and route selection performs as specified for all combinations of routes and all types of Operator login used at SEPTA, and that associated signage and public address outputs are triggered.

15.7.13.6.2 Signage Control

Validate proper operation of signage database triggered by APIS location signal, including dead reckoning. Ensure that information displayed on signs is as specified in Section 13, Vehicle Communication Systems.

15.7.13.6.3 PA Announcements Control

Validate proper operation of public announcements triggered by location signal, including dead reckoning. Ensure that content is as per Section 13.

15.7.13.6.4 Public Address

15.7.13.6.4.1 Sound Quality Testing Inside Vehicle

Measure and validate STI and sound level requirements as specified in Section 13, Vehicle Communication Systems

15.7.13.6.4.2 Sound Quality Testing Outside Vehicle

Measure and validate STI and sound level requirements as specified in Section 13.

15.7.13.6.4.3 Redundancy Testing

Validate redundancy within the public address system. Test the following conditions and demonstrate degraded operation of the public address system with coverage for all areas of the vehicle as per Section 13:

1. Loss of any one amplifier
2. Loss of any one speaker
3. Loss of any one branch circuit

15.7.13.6.4.4 Ad-Hoc Announcements

Validate operation of Ad-Hoc Public Address announcements. Tests performed shall include the following, as a minimum, as per Section 13:

1. Ability of Operator ad-hoc announcements to override prerecorded announcements.
2. Ability of Control Center ad-hoc announcements to override prerecorded announcements.

15.7.13.6.4.5 Assistive Listening System

Perform a type test demonstrating that the Assistive Listening System complies with the requirements in Section 13, Vehicle Communication Systems.

15.7.13.7 Automatic Passenger Counting (APC)

Validate proper operation of APC as per Section 13.

Validate offloading of APC data to wayside server as per Section 17, Controls, Networks, and MDS.

15.7.13.8 Event Recorder

Perform a type test demonstrating that the event recorder complies with the requirements for event recorders in Section 13, Vehicle Communication Systems.

15.7.14 Network Type Tests

15.7.14.1 Vehicle Network Integration Test

Comply with the following:

1. Perform a complete Network Integration Test (NIT) of all vehicle subsystems, including transmission through the trainline electrical coupler head, to determine network noise limits and to prequalify the proposed architecture of networks before vehicle implementation.

2. The NIT shall include vehicle power-up, power-down and changes of train makeup.

3. All subsystem controls connected to the digital data networks shall be actual units for a complete vehicle. Other coupled vehicles may use simulated traffic levels that mimic actual traffic levels.

4. The NIT shall verify that the protocols, datasets, and messages used on the network correspond to the Network ICDs and the specific signal, message, and dataset documentation provided for each subsystem.

5. The NIT shall verify that only allowed documented communications occur between functional networks.

15.7.14.2 Propulsion and Braking Network Test

The following tests are a summary of tests that are required, although further tests may be required to demonstrate compliance with the Specifications.

15.7.14.2.1 Propulsion Monitoring and Control

Perform tests to validate all propulsion monitoring and control interfaces specified in Section 10, Propulsion System and Control, and Section 17, Controls Networks and MDS.

15.7.14.2.2 Braking Monitoring and Control

Perform tests to validate all propulsion monitoring and control interfaces specified in Section 12, Friction Brake System, and Section 17, Controls Networks and MDS.

15.7.14.2.3 Propulsion to Braking Interfaces

Perform tests to validate all propulsion monitoring and control interfaces specified in Section 10 and Section 12.

15.7.14.2.4 CBTC Interfaces

Perform tests to validate CBTC interfaces to propulsion, brakes, and network specified in Section 10, Section 12, Section 13, Vehicle Communication Systems, Section 17, and Section 21, Communications Based Train Control.

15.7.14.2.5 Event Recorder

Perform tests to validate interfaces to other subsystems specified in Section 13 and Section 17.

15.7.14.2.6 PCN Time Synchronization Test

Perform tests to validate time synchronization from the vehicle master clock to propulsion, braking, event recorder, VCU, and ATC equipment as per Section 17.

15.7.14.2.7 Wayside Server Time, PCN Time, Communication System, and CCTV Time Comparison Test

Perform a detailed and comprehensive test to compare, evaluate, and identify time differences between all the time sources including Wayside Server Time, PCN Time, and communications subsystems specified in Section 17, Controls Networks and MDS.

15.7.14.2.8 Network Latency Test

Perform tests to validate appropriate network latency to support requirements specified in Section 17.

15.7.14.2.9 Network Redundancy and Failover Test

Perform tests to validate appropriate failover and continued uptime to support requirements specified in Section 17.

15.7.14.2.10 PCN Isolation Test

Perform tests to validate that MDS monitoring of propulsion, braking, event recorder, and CBTC equipment is possible, but that no network traffic into the PCN is permitted as per Section 17

15.7.14.3 Towing-Mode Network Integration Test

In addition to elements in the preceding section, test shall validate network Towing Mode requirements specified in Section 13 and Section 17

15.7.14.4 Train-to-Wayside Network Integration Test

Comply with the following:

1. Validate wireless network connectivity from vehicle to SEPTA wireless infrastructure.
2. Validate data flow and functionality from vehicle to wayside for elements specified in Section 13, Vehicle Communication Systems, and Section 17, Controls, Networks, and MDS.
3. Validate data flow and functionality from wayside to vehicle for elements indicated in Section 13 and Section 17.
4. Validate integration of wayside servers with SEPTA information technology assets.

15.7.14.5 CBTC Network Integration Test

Validate network integration required to accommodate CBTC requirements specified in Section 21, Communications Based Train Control.

15.7.14.6 Software and Firmware Security Assessment

Procure an independent third-party security assessment of software and firmware.

1. The security assessment shall be completed for the following categories of software and firmware:
   a. Software specifically developed or modified for this project (Category A software as defined in Section 18, Systems and Software Engineering); this requirement applies to all software provided on this project.
   b. Software re-used for this project (Category B software as defined in Section 18, Systems and Software Engineering); this requirement applies to Software-based subsystems functioning on the Propulsion Control Networks (PCN) only.
2. The subject security assessment and corresponding requirements specified in this section shall be implemented as per the following Security Controls from National Institute of Standards and Technology (NIST) SP 800-53 Rev. 5: CA-1, CA-2, CA-5, CA-7, CM-3, RA-1, RA-3, SA-11, SI-2, SI-3, SI-12.
3. The assessment shall be performed by an experienced, independent organization authorized to provide services to the US Government that maintains an active facility security clearance in good standing.
4. The assessment shall be performed by personnel cleared at any level, I.e., confidential, or above, under the facility clearance of the independent organization.
5. Furnish the name of the independent assessment organization. The independent third-party is subject to SEPTA Approval.
6. Ensure that the independent assessment organization will directly mail to SEPTA, on its company letterhead, details of its facility clearance level, including:
   a. Commercial and Government Entity (CAGE) code
   b. US Government entity granting the facility clearance
   c. Date of expiration of facility clearance
7. For all source code that is subject to the independent assessment of software and firmware security, submit documentation confirming that the source code does not include date/time-dependent functions.
8. Ensure that the third-party software security assessment provider shall check software and firmware to ensure that critical application security weaknesses (including (Open Web Application Security Project (OWASP's) Top 10 and SysAdmin, Audit, Network and Security (SANS') Top 25 Most Dangerous Software Errors) are addressed.
9. Ensure that the third-party security assessment provider performs the software security assessment using methodologies such as Fuzz, Dynamic, and Static testing. Submit the third party's Software Security Assessment Plan prior to performing the assessment for **approval**.

10. Ensure that the results of each independent software and firmware security assessment are sent directly from the third-party provider to SEPTA and the Contractor.

11. Submit a response to the third-party's assessment including plans to correct identified vulnerabilities.

12. This independent assessment of software and firmware security (including the Contractor's response and Corrective Action Plan) shall be performed during the following time periods, at any time of SEPTA's choosing within these periods:

    a. One assessment after completion of the Complete Vehicle First Article Inspection and before conditional acceptance of the Pilot Vehicles.

    b. One assessment after the conditional acceptance of the Pilot Vehicles, but prior to completion of conditional acceptance of all vehicles.

13. The Contractor shall be responsible for implementing corrective actions to address vulnerabilities that are identified during an independent assessment of software and firmware security that would prevent the final product from meeting the security requirements defined in TS 17.4.11.

15.7.14.7 Penetration Testing

Procure an independent third-party penetration test (also referred to as a vulnerability assessment).

1. The penetration test and corresponding requirements specified in this section shall be implemented in accordance with NIST SP 800-115 and as per the following Security Controls from NIST SP 800-53 Rev. 5: CA-1, CA-5, CA-7, CA-8, RA-1, RA-3, RA-5, SI-12.

2. This penetration test shall be performed by a qualified, independent organization authorized to provide services to the US Government that maintains a facility security clearance in good standing.

3. The penetration test shall be performed by personnel cleared at any level, I.e., confidential or above, under the facility clearance of the independent organization.

4. Furnish the name of the independent test organization. The independent third-party is subject to SEPTA Approval.

5. Ensure that the independent test organization will directly mail to SEPTA, on company letterhead, the details of its facility clearance level, including:

    a. CAGE code

    b. US Government entity granting the facility clearance

    c. Date of expiration of facility clearance

6. Submit the independent third-party's test plan and associated procedures for **approval**. The penetration test shall cover all products included in or incidental to this procurement, as specified in the Specifications.

7. Perform penetration testing on all vehicle and train-to-wayside networks to reveal and report potential network vulnerabilities.

8. Perform penetration testing on all subsystems to reveal and report potential application vulnerabilities.

9. Perform subsystem penetration testing from the vehicle-level connection point(s).

10. Perform penetration testing from both inside the car networks and from SEPTA wayside connections.

11. Ensure that the results of each independent penetration test are sent directly from the third-party provider to SEPTA and the Contractor.

12. Submit a response to the third-party penetration test, including a Corrective Action Plan to correct identified vulnerabilities subject to SEPTA’s **approval**.

13. This independent penetration test shall be performed during the following time periods, at any time of SEPTA’s choosing within these periods:

    a. One penetration test after the completion of the Complete Vehicle First Article Inspection and before conditional acceptance of the Pilot Vehicles.

    b. One penetration test after the conditional acceptance of the Pilot Vehicles, but prior to completion of conditional acceptance of all vehicles.

14. The Contractor shall be responsible for implementing corrective actions to address any vulnerabilities that are identified during the penetration test that would prevent the final product from meeting the security requirements defined in TS 17.14.11.

15.7.15 Monitoring and Diagnostic System Type Test

Before shipping the first vehicle's Monitoring and Diagnostic System (MDS) equipment, perform a functional laboratory test. The test shall include the following:

1. Shall validate the correct reporting of data to MDS over the vehicle network and train network, including all required vehicle system events and variables.

2. Shall demonstrate full performance of the MDS with all subsystems and full functionality of TOD. The Contractor may need to simulate fault conditions to complete this test requirement. Fault simulation procedures shall be included in the test procedure.

3. Shall minimally test failure conditions or fault conditions for all equipment reporting fault conditions to MDS as per Section 17.

4. Shall test energy consumption reporting requirements as per Section 9, 10, and 17.

15.7.16 CBTC System Type Test

Test shall be performed by the CBTC equipment supplier at the CBTC equipment supplier's facility on a complete vehicle-borne CBTC system to demonstrate compliance with the requirements of Section 21, Communications Based Train Control.

1. Functional Tests:
    a. Perform by simulating inputs from the vehicle systems and recording CBTC output commands.
    b. Perform test while the CBTC equipment is subjected to the specified environmental and input variations.
    c. Perform any further testing required to validate safety requirements imposed by CBTC supplier for safe operation.
2. EMI Tests: Perform to verify the immunity of the system to EMI in compliance with the EMI requirements in Section 2, Design and Performance Criteria.

15.7.17 Low-Location Exit Path Marking Type Test

Perform third party type test on at least one representative vehicle of each Low-Location Exit Path Marking (LLEPM) layout in accordance with APTA RT-VIM-S-022-10.

15.8 Vehicle-Level Type Tests at Contractor's Facilities

15.8.1 General

Perform vehicle-level static and dynamic type tests on the first fully assembled vehicle to confirm that the overall vehicle design complies with the Specifications:

1. In general, perform static tests at the Contractor's facilities or at other specified facilities and dynamic tests at SEPTA's facilities. The Engineer will consider allowing some tests, or subsets of these tests to be performed at the Contractor's facilities.
2. Perform a complete, orderly, and comprehensive test of each vehicle system to verify systems integration and the proper operation of each system, whether specifically specified below or not.

15.8.2 Vehicle-Level Static Type Tests at Contractor's Facilities

15.8.2.1 General

Testing at the Contractor's facilities shall include, at a minimum the following tests. Develop and submit test plans for each of the subject tests as part of the design development of each system.

1. Electrical system continuity and resistance tests to confirm that all electrical circuits are properly wired and have the appropriate electrical isolation and resistance measurements.

2. Weight distribution and balance test to confirm the vehicle complies with specified requirements

3. Trainline type test to confirm all trainline functions comply with design requirements as specified in Section 4, Coupler, Section 10, Propulsion System and Controls, Section 13, Vehicle Communication Systems, and Section 17, Controls, Networks, and MDS.

4. Warning devices type test to confirm functions comply with design requirements as specified in Section 13, Vehicle Communication Systems.

5. Friction brake system test to confirm the friction brake system complies with design requirements, as specified in Section 12, Friction Brake System.

6. HVAC system type test to confirm the HVAC system complies with design requirements (specified below) as specified in Section 7, HVAC.

7. Door system (specified below) and bridge plate system type test to confirm the door system complies with design requirements, as specified in Section 6, Passenger Doors.

8. Lighting system type test to confirm the lighting system complies with design requirements (emergency lighting is specified below) as specified in Section 8, Lighting.

9. Primary, auxiliary, and battery power system type tests to confirm the systems comply with design requirements as specified in Section 9, Electrical Equipment.

10. Communications system type test to confirm the system complies with design requirements as specified in Section 13, Vehicle Communication Systems.

11. Fare collection system type test to confirm the system complies with design requirements.

12. Vehicle data network and diagnostics system type tests to confirm the systems complies with design requirements as specified in Section 17, Controls, Networks, and MDS.

13. Train control (CBTC) system type test to confirm system complies with design requirements as specified in Section 21, Communications Based Train Control.

14. Radio interference type tests to confirm system complies with Radio Interference study produced to meet requirements in Section 2, Design and Performance Criteria.

15 Roll angle and static clearance testing to confirm vehicle complies with Specification requirements.

15.8.2.2 Vehicle HVAC System Type Test

Test the vehicle HVAC system to verify compliance with the requirements of Section 7, Heating, Ventilating, and Air Conditioning, with assistance from the HVAC unit manufacturer.

Test Setup:

1. This test shall be conducted in a climate room, or in an enclosed facility, such as a paint booth, where the "ambient" temperature and humidity requirements specified in Section 7 can be achieved.

2. Use electric baseboard heaters and humidifiers to simulate the passenger, sensible and latent, and solar loads inside the vehicle.

3. All tests shall be conducted at the nominal, minimum, and maximum supply voltages.

Test Steps:

1. Perform a vehicle Heat Transfer (UA Factor) Test.

2. Expose the vehicle to high ambient temperature condition specified in Section 7 for minimum 6 hours, without HVAC system operation ("soaking period").

    a. Following the soaking period, perform a pull-down test, and measure the time required to reach the required vehicle interior temperatures and stabilize. Pull-down time shall be **approved** and part of the cooling load calculations specified in Section 7.

    b. Include a cooling test at the design conditions of Section 7 and the cooling tests required in the Unitized HVAC System Type Test section, above, except simulate actual interior passenger and solar loads inside the vehicle, instead of regulating the return air temperature.

    c. After stabilizing for each test condition, record the temperatures every minute for 30 consecutive minutes in order to determine temperature swing as the HVAC equipment cycles.

    d. Include a door cycling test at the cooling design conditions of Section 7 with all internal design heat loads.

    e. Include a Layover Cooling test at conditions specified in Section 7.

    f. The test shall also verify proper operation of HVAC equipment during cooling operation.

    g. Include all abnormal heating condition tests and a back-up protection test as specified in the following sections:

        - Abnormal Heating Condition, Restricted Air
        - Abnormal Heating Condition, No Air
        - Back-Up Protection Test

3. Expose the vehicle to the heating design condition specified in Section 7 for minimum 6 hours, without HVAC system operation ("soaking period").

    a. Following the soaking period, perform a pull-up test to the Layover condition, and measure the time required to reach the required vehicle interior temperatures and stabilize. Cab

heaters may be used for this test. Pull-up time shall be **approved**, and part of the heating load calculations specified in Section 7.

b. Include a pull-up from the Stable Layover condition to the design interior condition. Pull-up time shall be **approved**, and part of the heating load calculations required in Section 7.

c. Include a heating test at the design conditions of Section 7, with and without passenger loads.

d. Include a test of the cab heating system and defrosting/defogging system at the design conditions and requirements of Section 7.

e. Include a test of all protective heaters and protective heating devices at the design conditions and requirements of Section 7.

f. After stabilizing for each test condition, record the temperatures every minute for 30 consecutive minutes in order to determine temperature swing as the HVAC equipment cycles.

g. Include a door cycling test at the heating design conditions of Section 7, without solar or passenger load.

h. The test shall also verify proper operation of HVAC equipment during heating operation.

Measurements During and After Tests:

1. Use data logging equipment to record temperature at a minimum of 30 locations throughout the vehicle, representative of seating and standing passengers, including Operator's cab and articulation section.

2. Record all significant events and data (such as refrigeration and heating equipment cycling), with corresponding temperatures and pressures as applicable for each test.

3. After all tests have been completed, take samples of the refrigerant for analysis for contaminants by an **approved** laboratory.

Test Results:

1. Vehicle interior temperatures shall not exceed the temperature variation specified in Section 7.

2. Refrigerant and compressor crankcase oil test results shall conform to the requirements of AHRI Standard 700 with the following exceptions:

   a. Moisture level of up to 45 ppm maximum.

   b. High boiling residue may be as high as 5%.

15.8.2.3 Door Operation Type Test

In addition to testing the door system on the first vehicle to verify compliance with the requirements of Section 6, Passenger Doors, perform the following tests:

1. Operate each door for 1,000 continuous, trouble-free cycles. If a door or door control fails before the test is completed, correct the fault and start the test over from the beginning.

2. Independently test each door obstruction system, door sensitive edge, and additional **approved** obstruction detective method to verify compliance with door obstruction detection requirements in Section 6.

15.8.2.4 Emergency Lighting Type Test

Test emergency lighting in accordance with APTA RT-S-VIM-020-10.

15.8.3 Vehicle-Level Dynamic Type Tests at Contractor's Facilities

15.8.3.1 General

Vehicle Dynamic Type Tests may be performed at Contractor's facilities. However, if neither facility is adequate to perform all required dynamic tests, obtain track and test time at an alternate location at no additional cost to SEPTA, and as **approved**.

15.8.3.2 Propulsion and Braking System Type Tests

Submit a factory test program for the propulsion and braking system that confirms performance is compliant with design requirements specified in Section 10, Propulsion System and Control, and Section 12, Friction Brake System.

1. Include as many parameters as can be reasonably tested at the Contractor's facility in this test plan.

2. Submit a separate comprehensive dynamic test plan for Propulsion and Braking Testing at SEPTA.

15.8.3.3 Emergency Rescue Vehicle Clearance Type Test

Couple the first two completed vehicles, or vehicles as selected by SEPTA, and check the following in both pushing and towing modes:

1. Proper articulation: truck, anticlimber, vehicle-body, tow bar, cable, and hose clearance under the worst-case geometric requirements for these elements specified in Sections 3, Vehicle-Body Structure, 4, Coupler, and 11, Truck Assemblies.

2. Vehicle ends for proper inter-vehicle clearance.

3. All articulation interior, exterior, roof, and underfloor surfaces and linkages for smoothness of operation and clearance.

4. Tow bars for proper vertical and horizontal swing and for clearance from the truck, under-vehicle components, skirts, anticlimber and ground (top of rail).

5. All truck, trainline, and tow bar cables and hoses for clearance and the absence of stretching and chafing.

6. Trucks for proper vertical and horizontal swing and for clearance from under-vehicle components and the skirts.

15.8.3.4 Preliminary Vehicle-Level EMI/EMC

Perform preliminary EMI/EMC testing on the first vehicle to demonstrate compliance with the emission limits specified in Section 2, Design and Performance Criteria. Use the test procedure prepared for the vehicle-level type test of EMI/EMC at SEPTA's facilities and perform portions of the test as suitable for the Contractor's test track.

15.8.3.5 CBTC System Type Test

Perform dynamic testing of the first vehicle at the test track at the Contractor's facility to confirm the functionality of the CBTC system with inputs that are representative of SEPTA CBTC wayside system communication and control inputs.

Submit a CBTC test plan as part of the CBTC design phase. See Section 21, Communications Based Train Control, for test track requirements.

15.8.3.6 Not Used

15.8.3.7 Vehicle Wash Mode Test

Perform test to confirm that the vehicle meets all the performance requirements as specified in Section 10, Propulsion System and Control.

15.9 Component Routine Tests

15.9.1 General

Each component shall be routine tested by its manufacturer during production before installation at the vehicle manufacturing site. Each test of electrical equipment shall include an insulation test.

15.9.2 Air Conditioning Unit Routine Tests

Perform the following tests:

1. Leak testing: Confirm compliance with refrigerant leak test requirements specified in Section 7, Heating, Ventilating, and Air Conditioning.

2. Evacuation testing: Confirm compliance with evacuation test requirements specified in Section 7.

3. Air conditioning unit test:

    a. Apply a heat load to both the evaporator and condenser coils.

b. Operate the HVAC unit for at least 8 hours throughout its cooling modes of operation, at least 4 hours in full cooling and 4 hours in mixed modes of partial cooling.

c. Perform a complete functional test to verify capacity modulation, control points of pressure transducers or switches, and return air and fresh air thermostatic control points.

d. Record the following:

- Power consumption of motors
- Evaporator and condenser fan motor speeds
- System pressures and temperatures
- Applied loads to the evaporator and condenser
- System refrigerant charge
- Refrigerant condition (wet or dry)

e. Correct abnormal conditions and repeat the associated test.

4. Unit heat staging and function of overheat protection devices: Verify performance as specified in Section 7.

5. Watertightness test:

a. Ventilation blower assemblies and condenser fans shall be running at the rated design speeds.

b. Conduct the water test of the HVAC unit per requirements of Watertightness Routine Tests section and following ASHRAE Guideline 23.

c. There shall be no evidence of water ingress into the HVAC unit, condenser fan motor junction box(s), or compressor motor junction boxes.

6. Insulation resistance and dielectric (high potential) tests: Performed by the manufacturer on each unit in accordance with the Insulation Testing section, above.

15.9.3 Motor Routine Test

Perform a routine test on each traction motor, ac auxiliary motor, and dc motor:

1. Perform in accordance with IEC 60349, as appropriate.
2. Dynamically test motor balance in accordance with IEC 60349.

15.9.4 Traction Gear Unit Routine Test

Each traction gear unit shall be tested using the manufacturer's routine test. The test shall include the following as a minimum:

1. Check gear tooth mesh alignment, backlash, and shaft endplay to verify that it is within the manufacturer's tolerances before the gear unit is operated.

2. No load operation at maximum operating speed equivalent vehicle speed for 10 minutes in each direction. Continuously monitor vibration produced by each gear unit and gear sump oil temperature.

Gear units that produce abnormal oil temperature or noise shall be rejected.

15.9.5 Pantograph Routine Test

Perform a routine test on each pantograph:

1. Test in accordance with IEC 60494-2 to verify compliance with the Specifications.

2. Test insulation per the Insulation Testing section, above.

15.9.6 Traction Inverter Routine Test

Perform a routine test on each traction inverter:

1. Test in accordance with IEC 61287-1 to verify compliance with the Specifications.

2. Test insulation per the Insulation Testing section, above.

15.9.7 Auxiliary AC Inverter Routine Test

Perform a routine test on each ac inverter:

1. Test in accordance with IEC 61287-1 to verify compliance with the Specifications.

2. Test insulation per the Insulation Testing section, above.

15.9.8 DC LVPS and Battery Charger Routine Test

Perform a routine test on each LVPS:

1. Test in accordance with IEC 61287-1 to verify compliance with the Specifications.

2. Test insulation per the Insulation Testing section, above.

15.9.9 Battery Routine Test

Perform a capacity test on 5% of the batteries supplied at the point of manufacture:

1. Test in accordance with IEC 60623, Section 4.2.1, Discharge Performance at 20 °C.

2. The test shall be at the 5-hour rate, at 20° C (68° F) ambient temperature.

15.9.10 Friction Brake Routine Tests

Test each component and system that is part of the friction brake system. Perform the following tests:

1. Electrical and electronic assemblies:

   a. Test insulation per the Insulation Testing section, above.

b. Perform functional test and certify for performance in accordance with manufacturer's specifications and test codes.

2. Pneumatic pump unit: Perform a functional test and a capacity test. If hydraulic, perform applicable capacity test.

3. Valves: Perform functional test and certify for performance in accordance with manufacturer's specifications and test codes.

15.9.11 Communication Systems Routine Test

Test each electrical and electronic assembly that is part of a system specified in Section 13, Vehicle Communication Systems.

1. Test insulation per the Insulation Testing section, above.

2. Perform a functional test and certify for performance in accordance with manufacturer's specifications and test codes.

15.9.12 Trainline Electric Connection Head Routine Tests

Perform the following tests:

1. Electrical and electronic assemblies: Test insulation per the Insulation Testing section, above.

2. Perform functional test and certify for performance in accordance with manufacturer's specifications and test codes.

15.9.13 Truck Frame Welds Routine Test

Perform the following inspections in accordance with the Non-Destructive Testing and Inspection section, above:

1. Each production truck weld:

   a. Perform magnetic particle or dye penetrant inspection.

   b. Includes welds on the frame, bolster, and other primary structural members.

2. Critical welds:

   a. Inspect by radiography or by section and etch.

   b. Perform on the first and fifth production trucks, and thereafter 5% of the trucks chosen at random.

3. Cast trucks: Perform magnetic particle inspection on 100%.

If defects are found during sampling inspection, positively locate the beginning of such defects in previous truck frames and apply appropriate corrective action.

15.9.14 Wheel Back-to-Back Routine Test

Measure each wheel-axle assembly to verify conformance with back-to-back distance requirements.

15.9.15 Resistance Routine Tests

Perform test for each truck, isolating the other trucks during the test. Test shall be performed by sending current through the circuit, not by using an ohmmeter.

1. Vehicle-Structure to Wheels Resistance Routine Test: Measure grounding system resistance between vehicle structure and wheels.
2. Propulsion System to Wheels Resistance Routine Test:
    a. Measure grounding system resistance between the propulsion system return bus and wheels.
    b. Test shall be via the ground brushes separate from the safety ground system.
3. Wheel Shunt Resistance Routine Test:
    a. Measure wheel-axle-wheel and wheel-axle-ground brush assembly to verify conformance to shunt resistance values specified in Section 11, Truck Assemblies.
    b. Measure values for each wheelset with other wheelsets isolated from the measurement.
    c. Measure wheel tread to stub axle before installation, or with ground brush disconnected for installation, or with ground brush disconnected.

15.10 Vehicle-Level Routine Tests at the Contractor's Facilities

15.10.1 General

After installation of components and systems on the vehicle, perform routine tests to verify that equipment functions as expected within the vehicle's nominal mechanical, electrical, and physical environments, and interacts with other systems correctly:

1. Each test shall be in accordance with the specified standards or an **approved** test plan.
2. All test plans shall include procedures furnished by, or approved by, the equipment manufacturer.
3. Include test reports in each Vehicle History Book as specified in Section 20, Program Control and Quality Assurance.
4. All pre-delivery testing shall be performed at the Contractor's facility. The Contractor is not permitted to perform pre-delivery dynamic tests on SEPTA property.

15.10.2 Vehicle-Level Static Routine Tests at the Contractor's Facilities

Comply with the following:

1. Perform tests for all equipment and systems on each vehicle at the Contractor's facilities prior to shipment, whether specified in this Section or not.
2. Where external inputs or signals are required for verification, such as for TWC, use test equipment furnished by the equipment supplier, or built to supplier specifications.
3. Where insulation testing is specified, perform in accordance with the Insulation Testing section, above.

15.10.2.1 Vehicle-Level Routine Functional Tests

Perform a functional test on each vehicle system to verify correct operation and integration with other vehicle systems. This is not intended to repeat component manufacturer's routine tests.

15.10.2.2 Vehicle-Level Routine Wiring Tests

Perform each test listed below after the wiring and equipment installation is complete. Confirm integrity of electrical insulation and connections:

1. Wiring Continuity Checks:
    a. Test each circuit to ensure continuity and correct polarity of equipment and devices.
    b. Check each frame ground and terminal connection for tightness.
2. Insulation Resistance Test: Conduct in accordance with the Insulation Testing section, above.
3. Dielectric (High Potential) Test: Conduct on each circuit in accordance with the Insulation Testing section, above.

15.10.2.3 Vehicle-Level Routine Watertightness Tests

Perform watertightness tests specified below on each vehicle. Perform tests before installation of sound deadening material, thermal insulation, and interior finish.

1. Vehicle: Perform a complete watertightness test on all areas of the vehicle sides, ends, and roof, including doors and windows:
    a. Spray water from nozzles maximum 1 meter from, and aimed directly at the surface being tested.
    b. Deliver minimum 26 liters per minute to each square meter of surface being tested, with minimum nozzle velocity of 45 meters per second.
    c. Continue spray applications for 10 minutes before inspection for leaks begins, and run continuously during the inspection.

2. HVAC: Conduct HVAC watertightness test as part of the vehicle watertightness test, with blowers operating.

3. Equipment Enclosures: During the test of the vehicle body, conduct the enclosure watertightness test on individual underfloor and roof-mounted enclosures required to be watertight:

   a. Direct spray at the exposed sides and ends of the boxes as would normally occur during vehicle washing operations.

   b. Direct spray as appropriate to simulate water spray from the wheels.

4. Traction Motor Leads: Water test traction motor lead connections. Water flow rate and velocity shall be the same as for the vehicle water test.

15.10.3 Cab Controls Routine Test

Perform routine tests to confirm all cab control devices perform in compliance with design requirements as specified in Section 5, Operator's Cab Controls.

15.10.4 Vehicle-Level Dynamic Routine Tests at the Contractor's Facilities

Perform dynamic routine tests at the Contractor's Facilities before shipment of vehicle:

1. Testing shall be performed at speeds up to the maximum design speed, as specified in Section 2, Design and Performance Criteria.

2. The following tests are a minimum:

   a. Propulsion

   b. Dynamic and friction braking

   c. Propulsion system/door system interlocks

3. Perform testing for dynamic stability at the Contractor's facilities for each vehicle that has a specific wheel profile. Testing shall confirm vehicle stability under pre-defined worst-case track conditions. Test results shall be presented for each vehicle with unique wheel profiles.

15.11 Contractor's Use of SEPTA's Facilities

15.11.1 Contractor's Maintenance Facility Use

The Contractor will be allowed by SEPTA to use a portion of the yard tracks and the automotive parking lot at a shop designated by SEPTA.

1. The Contractor is responsible for providing office trailers for its use and for arranging for electricity and telephone service at Contractor's expense.

2. The Contractor shall use this site to prepare vehicles for acceptance testing and to perform modification or rework required on vehicles under its control prior to acceptance, as well as warranty work.

3. SEPTA will supply at no charge to the Contractor the OCS power, tracks, Operators, and supervisors as required for yard movement of vehicles.

15.11.2 Contractor's Track Use

SEPTA will designate the hours (during off peak and late evening/overnight periods in general) that tracks will be available for testing.

1. SEPTA will assign Operators as requested by the Contractor.

2. Contractor shall give a minimum of 10 days' written notice of Operator and track requirements to the Engineer and a minimum of 48 hours written notice when canceling or postponing a previously scheduled test.

3. In all cases, SEPTA's requirements will have priority. No assurance is given to the Contractor that the requested number of hours per day, time of day, or number of days per week of track time will be available for testing.

15.12 Pilot Test Program

15.12.1 General

Conduct a Pilot Test Program of the pilot vehicles on SEPTA's light rail system to validate vehicle performance and design compliance.

1. The Pilot Test Program is designed to expose the pilot vehicles to SEPTA's operating environment during a prolonged period to confirm that the vehicles will work properly under conditions experienced at SEPTA.

2. Perform the Pilot Test Program on two pilot vehicles that are built to the design requirements of this Project.

3. One vehicle shall be designated to operate on the City Division Lines and the other shall operate on the Suburban Division Lines.

4. The vehicles are expected to operate in simulated revenue service and accumulate a minimum of 4,000 miles of operation (per vehicle) during the Pilot Test Program.

15.12.2 Pilot Test Program Schedule

The Pilot Test Program shall commence after the Design Phase and prior to the Revenue Service Production Phase.

1. The vehicles shall be shipped to SEPTA for the Pilot Test Program and shipped back to the Contractor's facility for inclusion in the production program.

2. The pilot vehicles shall be reworked by the Contractor to conform with the approved design and production specifications of the delivered revenue service vehicle fleet and shall be inserted into the delivery and testing program as the last two vehicles.

3. It is expected that the Pilot Test Program will be conducted over an eight-month period that bridges seasonal weather extremes.

15.12.3 Pilot Vehicle Maintenance

During the Pilot Test Program, the Contractor is responsible for all maintenance and inspection work, maintenance materials, and maintenance labor, and shall work closely with SEPTA to access facilities required for maintenance.

15.12.4 Pilot Test Program Requirements

The following requirements shall be included in the Contractor’s Pilot Test Program and presented in detail as part of the Pilot Test Program Plan submitted at the time of Proposal and made part of this Contract.

The Pilot Test Program shall be comprised of vehicle system level testing and simulated revenue service testing.

15.12.5 Pilot Vehicle System Level Testing

The pilot vehicles shall undergo a series of static and dynamic tests to evaluate performance of vehicle systems.

1. Submit test procedures for **approval** for the following systems and conduct these procedures as part of the Pilot Test Program.

2. More tests may be deemed necessary by the Contractor; the specified lists are minimum requirements. All test results shall be communicated with SEPTA as part of the Pilot Test Program.

15.12.6 Pilot Vehicle Static and Dynamic System Tests

Perform the following tests as a minimum:

1. Primary Power: Test range of inputs for necessary primary power output to support vehicle systems.

2. Auxiliary Power: Test auxiliary power output under design range of variable input conditions to confirm output acceptable performance.

3. Braking System: Confirm brake system performance complies with specified requirements.

4. Train Network: Confirm train network provides desired level of connectivity to vehicle systems.

5. Ride Quality and Dynamic Stability: Apply instrumented wheelsets to vehicle and associated data recording equipment to perform dynamic stability testing on representative segments of SEPTA tracks operating at a range of speeds from maximum authorized speed to low speed.

6. Noise Testing: Perform static and dynamic interior and exterior noise testing to verify vehicle complies with specified requirements.

7. Wheel Spin/Slide Testing: Perform testing of wheel spin/slide system to confirm performance complies with design requirements as specified in Section 2, Design and Performance Criteria and Section 12, Friction Brake System.

8. Traction Performance: Test traction performance to confirm acceleration and dynamic braking performance meets design requirements as specified in Section 10, Propulsion System and Controls, and Section 12, Friction Brake System.

9. HVAC: Test HVAC system performance to confirm cooling and heating meet design requirements as specified in Section 7, HVAC.

10. Doors: Confirm door system and all door interlocked systems perform in accordance with design requirements as specified in Section 6, Passenger Doors.

11. CBTC: Test CBTC system performance to confirm onboard CBTC system performs in compliance with design and system requirements.

12. Clearance: Perform dynamic clearance check to confirm the vehicle meets specified clearance envelope requirements.

13. EMI: Perform testing to confirm the vehicle meets EMI requirements under complete range of acceleration and braking conditions.

14. Communications: Confirm all train-to-wayside communication systems perform as designed on the entire SEPTA Trolley network.

15. Radio interference tests to confirm system complies with Radio Interference study produced to meet requirements in Section 2, Design and Performance Criteria.

16. Lighting: Confirm the lighting systems work in accordance with design requirements as specified in Section 8, Lighting.

15.12.7 Pilot Vehicle Simulated Revenue Service Testing

The pilot vehicles shall be put through a simulated revenue service test program in which they operate on a number of daily regular service runs without passengers. The vehicles will operate on both the Suburban and City Division Lines as part of the simulated revenue service test program.

1. Load the vehicles to AW3 using water tanks to simulate passenger loading.

2. Open and close all vehicles doors as though making actual station stops.

3. Maintain a daily log to record any issues experienced by the vehicles. Record all anomalies in vehicle performance and communicate with SEPTA.

15.12.8 Pilot Test Program Documentation

Upon the completion of all required engineering tests associated with the Pilot Test Program, all test procedures, reports, and **approvals** shall be copied and submitted to the Engineer in a single volume.

15.13 Vehicle-Level Dynamic Type Tests at SEPTA's Facilities

15.13.1 General

Perform these tests on the Project alignment or at other facilities, as directed by SEPTA.

1. Perform tests on the first or second vehicle.

2. Demonstrate compliance with performance specified in Section 2, Design and Performance Criteria, and other sections of the Specifications for a fully assembled vehicle.

3. If it is determined that a ”common” wheel profile is not be suitable for use on both the City Division and Suburban Division, where applicable, Vehicle-Level Dynamic Type Tests shall be performed on both pilot vehicles.

4. Perform testing for dynamic stability at SEPTA's facilities for each vehicle that has a specific wheel profile. Testing shall confirm vehicle stability under predefined worst-case track conditions. Furnish test results for each vehicle with unique wheel profiles.

5. Make two runs in each direction for each dynamic test, as a minimum.

6. Select, with SEPTA's concurrence, a suitable test segment:

   a. Determine where each test will start, based upon right-of-way restrictions, grades, speeds, clearances, safety considerations, and other limitations at SEPTA's facilities.

   b. Locations shall be such that the opposite direction test run is run over the same portion of the alignment.

   c. Mark the start location for each test.

7. If the vehicle or apparatus fails to satisfy the specified performance and design criteria, redesign the vehicle and retest. If modifications are necessary, they shall be made on a fleetwide basis.

15.13.2 Setup for Vehicle-Level Dynamic Type Tests

15.13.2.1 Instrumentation

Comply with the following for instrumentation:

1. All data shall be continuously recorded by a digital data acquisition system using appropriate transducers and sensors, except as otherwise indicated. The Contractor may propose alternate methods of instrumentation for the Engineer's approval.

2. The test procedure shall comply with the Test Procedures section, above, and include a detailed description of the data acquisition system.

   a. Annotated copies of catalog cuts may be used for parts of the description.

   b. Include an explanation of the accuracy of the instrumentation.

c. Include typical logging sheets, print outs, plotting forms, and examples of any other data sheets for the test or in the final report.

3. All gauges, instruments, and transducers/sensors shall be calibrated before the test and shall remain calibrated for the duration of the test.

   a. Calibration certificates shall be available for inspection by the Engineer or approved by the Engineer on the day prior to the commencement of the test.

   b. The methods of calibration and time periods for recalibration shall be in accordance with the test laboratory's national standard or ISO standards. The laboratory shall have on file a current certification of calibration traceable to the laboratory's national standard.

   c. The test procedure shall include a copy of the current calibration certification for each instrument and gauge to be used for the test.

4. Use personnel familiar with the setup and function of instrumentation and equipped to handle troubleshooting the test setup in the field, to limit testing delays.

5. For vehicle type tests, instrument each vehicle with a Contractor-furnished multi-channel data acquisition system, which shall produce a permanent test record (both electronically and hard copy):

   a. The data acquisition system shall be capable of interfacing with all major systems through a serial bus or other **approved** method.

   b. Wherever possible, applicable signals needed to verify vehicle performance shall be obtained from the serial interface or other **approved** method with the equipment in question instead of hardwiring to obtain the desired signals.

6. Provide all recorders, sensors, transducers, pickups, equipment racks, test wiring termination panels, calibration equipment, wiring, and inverters necessary to operate this instrumentation.

   a. Test wiring-termination-panels shall include test jacks and switching for each channel to permit calibration signals to be injected into each recorder channel without requiring wiring or connectors to be disconnected. Arrange so that calibration signals cannot be fed back into the monitored equipment.

   b. Provide isolation amplifiers and voltage dividers to isolate the inside vehicle instrumentation wiring and equipment from high voltages. Exposed terminals with potential differences greater than 50 V are prohibited.

7. Instrumentation shall be powered from the vehicle LVPS.

   a. The equipment shall function over the specified LVPS voltage range specified in Section 9, Electrical Equipment.

   b. Internal combustion engines driving a generator or use of the vehicle inverter power will not be permitted.

8. The accuracy and response of the instrumentation shall be sufficient to determine compliance with the Specifications.

15.13.2.2 Channel Assignments

For each test, permanently record the following channel assignments simultaneously:

1. Acceleration (positive and negative): The signal shall be produced by an independent accelerometer:
    a. Type: Inertial
    b. Range: +/- 1g
    c. Acceleration/deceleration rates calculated by the propulsion or friction brake system are not considered acceptable for this requirement
2. Tractive effort response: Each truck
3. Tractive effort demand: Each truck
4. Spin/slide system operation: Each truck
5. Brake cylinder pressure: Each truck
6. Brake disc temperature: On one powered-truck axle using thermocouples embedded in the brake pads
7. OCS voltage
8. Total OCS current drawn by each vehicle
9. Speed: Each axle
10. Propulsion and braking trainline command signals (or multiplexed to a single analog channel)
11. Track brake status
12. Inverter current: Each truck
13. Wheel temperature
14. GPS position
15. Distance
16. Secondary suspension pressure: Each truck
17. Sander operation
18. An independent time base with 1-second time intervals
19. Such channels as the Contractor feels necessary to record voltage transients
20. Five spare analog and ten spare digital channels for additional signals that may be requested by SEPTA

15.13.2.3 Measurement of Average Acceleration and Deceleration Rates

Where performance requirements specify average acceleration and deceleration rates (dv/dt) measure as follows:

1. Use the accelerometer, tractive effort, brake cylinder pressure, and speed signals.
2. Acceleration:
   a. Entry speed, per speed signal: End of jerk limiting, as indicated by tractive effort signal.
   b. End speed, per speed signal: Test speed is reached.
3. Deceleration:
   a. Entry speed, per speed signal:
      - Dynamic and blended MSB, MB: End of jerk limiting, as indicated by tractive effort signal.
      - 100% friction brake MSB, MB: 50% release of brake pressure, as indicated by the brake cylinder pressure signal.
      - EB: 50% release of brake pressure, as indicated by the brake cylinder pressure signal.

   b. End speed, per speed signal:
      - Speed signal is zero, or
      - Accelerometer reads zero (accelerometer signal crosses acceleration axis on chart)
4. Determine the elapsed time from the entry speed to the end speed of the test.
5. Calculate average dv/dt: (Entry speed - End speed) / Elapsed Time.
6. Disputes over interpretation of recorded values and calculations will be resolved by the Engineer.

15.13.3 Propulsion and Braking Dynamic Type Tests

15.13.3.1 Propulsion Tests

Perform the following tests as a minimum:

1. Acceleration rates and balancing speed for five evenly-spaced tractive effort commands, accelerating from a stop.
2. Time to travel 1 km (0.6 mi) from a standing start with a maximum power command.
3. Acceleration performance during the AW3 braking tests required in the following section.
4. Confirm performance of the overspeed protection system.

Run the tests at AW0 and a second series of tests at AW2. Monitor braking during tests.

15.13.3.2 Braking Tests

Perform the following tests as a minimum:

1. Full service brake stops from 80, 70, 50, and 25 km/h (50, 43, 31, and 16 mph)
2. Minimum brake stops from 15 km/h (9 mph)
3. All-friction full service brake stops from 70, 50, and 25 km/h
4. All-friction minimum service brake stops from 15 km/h
5. Emergency stops from 70, 50, and 25 km/h
6. Tests designed to determine compliance of the track brake system with the Specifications

Run three series of tests:

1. At AW0
2. At AW2
3. At AW3

Before initiation of each friction-stop test, cool brake discs to a maximum of 120 C (248 F) as measured by thermocouples.

15.13.3.3 Thermal Capacity Tests

Demonstrate compliance with the specified duty cycle requirements.

15.13.3.4 Wheel Spin/Slide

Demonstrate compliance with wheel spin/slide requirements using all power and braking modes.

Monitor the following signals during spin/slide testing:

1. Tractive effort command and effort delivered per inverter
2. Pressure signals per truck
3. All wheel (or axle) speed signals on the spin/slide test vehicle
4. Adhesion level
5. GPS position
6. Distance
7. Sander operation
8. Propulsion and braking trainline commands

9. Acceleration

10. Spin/slide detection: Propulsion system

11. Slide detection: Friction brake system

15.13.3.5 Parking Brake

Perform a parking brake system test. Demonstrate compliance with performance requirements by measuring the force required to move the vehicle with the parking brake applied.

15.13.4 Tow Bar Dynamic Type Test

Comply with the following:

1. Rescue Operation: Demonstrate that an AW3-loaded, operational vehicle can push or tow an AW3 loaded, inoperative vehicle over the entire Project alignment, while operating under degraded performance and all brake rates without damage to the tow bar assembly, its attachments to the underframe, the underframe, or any other part of the vehicle body.

2. Trainline Type Testing:

   a. Demonstrate that, when coupled, a train of two vehicles performs as required to meet the Specifications.

   b. Demonstrate that all operational functionality is communicated across the tow bars.

15.13.5 Load Leveling Dynamic Type Test

Perform a test to confirm that the truck suspension elements are set properly, and the vehicle load leveling system is functioning properly and complies with Section 2, Design and Performance Criteria.

15.13.6 Load Compensation Dynamic Type Test

Perform a test to confirm that the load measuring system is functioning properly for each truck and that load compensation complies with Section 2, Design and Performance Criteria.

15.13.7 Ride Quality Type Test

Perform ride quality tests according to ISO 2631 to demonstrate compliance with the specified ride quality in Section 2, Design and Performance Criteria:

1. As a minimum, ride quality tests shall consist of operating the vehicle at speeds of [40 and 70 km/h (25 and 43 mph)], and maximum overspeed set point over track selected by SEPTA under two load conditions: AW0 and AW1. Weights used to simulate AW1 shall be provided by the Contractor.

2. Perform ride quality tests on both city and suburban divisions.

3. Provide and monitor instrumentation capable of measuring and recording the expected magnitude of vertical, longitudinal, and lateral shocks and vibrations concurrently, with speed and event marker.

4. Locate sensing units that measure in the three translation directions on the vehicle floor above the intersection of the vehicle longitudinal center line and the following:

   a. An end truck transverse center line

   b. A center truck transverse center line

   c. The center of one section of the vehicle between trucks

   d. At three seat locations at the bottom of the seat, as determined by SEPTA

   e. Clearly identify locations for acceleration measurements in the test procedures and obtain final **approval** before starting testing

5. Measure acceleration data over the frequency range of 0.5 Hz to 80 Hz.

6. Make ride quality measurements with fully functioning suspension systems with normal acceleration and braking levels in a simulated revenue service operation.

7. Acceptability of the ride quality will be determined by an analysis of the recorded rms accelerations and shall meet the requirements of Section 2.

15.13.8 Noise and Vibration Type Test

15.13.8.1 General

Perform sound level and vibration tests at AW0 vehicle weight, to demonstrate compliance with the specified limits in Section 2. Sound levels shall comply with the requirements of Section 2 with dynamic brakes cut in and cut out.

15.13.8.2 Noise Test

Provide noise test equipment necessary to perform tests to verify compliance with Section 2. Perform sound measurement per the following:

1. Take sound measurements on welded rail at-grade, newly-ground, and where reflections from nearby walls, floor, or other equipment will not influence the directly radiated sound by more than 2 dB.

2. Ambient sound level shall be minimum 10 dB below the sound level produced by the equipment being measured, when evaluated using the same scale or octave band.

3. Perform sound measurements using Type 1 sound level meters meeting current IEC or ANSI standards. Measure sound levels on the A scale (dBA), with slow meter response for stationary vehicle measurements, and with fast meter response for moving vehicle measurements.

4. Measure interior noise levels in accordance with ISO 3381.

5. Measure exterior noise levels in accordance with ISO 3095, with microphones placed 7.5 m (25 ft) from the track centerline, and 1.5 m (5 ft) above top-of-rail.

6. Test for each condition specified in Section 2, Design and Performance Criteria.

Record the following:

1. Description of sound level or vibration source being measured, including pertinent statistical information

2. Description of the environment where sound level or vibration source is measured, including a sketch showing source position

3. Operating conditions of sound level or vibration source during measurements

4. Pertinent meteorological data

5. Locations and orientations of microphones with respect to sound level source

6. Equipment used for making measurements

7. Description and measurements of ambient sound levels

8. Data obtained, including range of variation

9. Instrument settings, corrections, and calibration records

15.13.8.3 Vibration Test

Perform vibration test to demonstrate compliance with Section 2, as follows:

1. Provide test equipment necessary to perform the tests.

2. Test in accordance with IEC 61373 to verify compliance with the specified limits.

3. Confirm that the vehicle can operate without degradation of performance when subject to vibration and impacts encountered during normal service.

15.13.9 EMI/EMC Dynamic Type Tests

Perform EMI/EMC tests on the Project alignment:

1. Conduct tests with all wayside systems functioning, including but not limited to signals and TWC and CBTC. Testing shall confirm compliance with the EMI/EMC requirements in Section 2, Design and Performance Criteria.

2. Demonstrate compliance with EMI limits specified in Section 2, Design and Performance Criteria.

    a. Validate results considering worst-case conditions to comply with the EMI monitor requirements specified in Section 9, Electrical Equipment.

b. Worst-case conditions shall include all tolerances of the input filter, such as, but not limited to, loss of capacitance due to aging and worst-case location on the alignment.

3. Radiated Emission Testing: Perform in accordance with EN 50121-3-1, with the following qualifications:

a. Extend measurement range up to 6 GHz, with limits in the range 1 GHz to 6 GHz measured in accordance with EN 61000-6-4, Table 3, Requirements for radiated emissions - enclosure port, at 10 m, with limits decreased according to this distance.

b. Conduct measurements in the range 10 kHz to 150 kHz as cited in EN 50121-3-1 Annex C, Emission values for lower frequency range. In order to minimize impact of near-field effects and increase measurement certainty, Contractor may propose to carry out these measurements from a greater distance than that prescribed in EN 50121-3-1, with limits recalculated accordingly.

4. Conductive Emission Testing: Perform in accordance with UMTA-MA-06-0153-85-6 (NTIS PB88-136932), Method RT/CE02A, Conductive Emission Test, Vehicle, or **approved** equal, with the following addition for the TWC system:

a. Test for electromagnetic compatibility with the TWC system, operating at frequencies specified in Section 13, Vehicle Communication Systems, or as communicated by SEPTA.

5. Inductive Emission Testing: Perform in accordance with UMTAMA-06-0153-85-8, (NTIS PB87-194379) Method RT/IE01A, or **approved** equal, with the following addition for the TWC system:

a. Test for electromagnetic compatibility with the TWC system, operating at frequencies specified in Section 13 or as communicated by the Engineer.

15.13.9.1 Cab Signal Interference (CSI) Dynamic Type Test

Perform test with worst-case propulsion system emissions, including operation of any or all train equipment alone or in combination, and in normal, abnormal, and failed conditions.

1. Demonstrate that worst-case propulsion system emissions do not disturb the onboard cab signal system, with the required margin.

2. Demonstrate that the vehicle does not produce a rail current signal exceeding the requirements for CSI in Section 2, Design and Performance Criteria.

15.13.10 CBTC Static and Dynamic Type Tests

Perform static and dynamic type tests on track designated by SEPTA to demonstrate that all vehicle-borne CBTC equipment functions properly and is completely compatible with wayside equipment:

1. Tests shall include all possible wayside-to-vehicle and vehicle-to-wayside system possibilities and configurations.

2. Confirm compatibility of the CBTC-equipped vehicle with the wayside communications infrastructure.

3. Testing shall confirm the performance of vehicle overspeed protection.

4. Tests shall verify that a CBTC-equipped vehicle complies with the relevant requirements of Section 21, Communications Based Train Control, and meets performance requirements including, at a minimum:

    a. Train localization

    b. Driving mode changes (all)

    c. Enforcement of speed limits

    d. Enforcement of all types of stopping points

    e. Ability to run bidirectionally

5. Conduct tests for the following test train configurations:

    a. Test vehicle operating by itself and as part of a coupled train.

    b. Test vehicle operating in each available CBTC operating mode.

    c. Test vehicle operating in a degraded state, due to:

        - One failed/inoperative propulsion inverter
        - One failed/inoperative friction brake unit

6. Perform a safe braking distance test validating that the CBTC system, in combination with the vehicle braking system, conforms to SEPTA's safe braking distance model under worst-case conditions.

7. C See TS 13.2.9.3

15.13.11 Collision Avoidance System Dynamic Type Test

Perform testing to validate system complies with requirements of Section 21.

15.14 Vehicle-Level Routine Tests at SEPTA’s Facilities

15.14.1 Vehicle-Level Static Routine Tests at SEPTA’s Facilities

15.14.1.1 General

Perform the vehicle-level static routine tests listed below on each assembled vehicle prior to the vehicle-level dynamic routine testing. In addition to the tests listed, repeat other vehicle-level static routine tests performed at the Contractor’s facilities if requested by SEPTA.

15.14.1.2 Door, Door Operators and Controls

Test and adjust each door and its operating equipment:

1. Check the obstruction detection features for proper operation and adjust before the start of the cycling test. This feature shall operate properly, without the need for readjustment, at the end of the cycling tests.
2. Operate each door a minimum of 100 consecutive, successful cycles. Initiate cycling through the control line.
3. Before and after the above cycling, verify proper forces for opening and closing on each door.
4. If a door or controls fail before completion of the test, document correction of the failure and restart the test from the beginning.
5. Make any necessary adjustments to ensure smooth functioning, attainment of the required speed of operation, and specified operation of controls, signals and interlocks.

15.14.1.3 Bridge Plate, Bridge Plate Operators and Controls

Comply with the following, in addition to requirements for the Door, Door Operators and Controls Routine Test, above:

1. Test and adjust each bridge plate and its operating equipment.
2. Check the obstruction detection features for proper operation and adjust before the start of the cycling test. This feature shall operate properly, without the need for readjustment, at the end of the cycling tests.
3. Operate each bridge plate a minimum of 100 consecutive, successful cycles. Initiate cycling through the control line.
4. Before and after the above cycling, verify proper forces for extending and retracting for each bridge plate.
5. If a bridge plate or control fails before completion of the test, document correction of the failure and restart the test from the beginning.
6. Make any necessary adjustments to ensure smooth functioning, attainment of the required speed of operation, and specified operation of controls, signals and interlocks.

15.14.1.4 Heating

Perform a functional test of the heating system by simulation of inputs with the PTU:

1. Demonstrate operation of the thermostatic control system by using the PTU.
2. Apply heat to the overhead heaters without airflow and cycle the high-limit control switch three times.

3. During the test, record power consumption and verify proper operation of all controls.

4. The test shall be successful when the backup protection device is not activated.

15.14.1.5 Air Conditioning

Test the air conditioning system by simulating inputs with the Portable Test Unit (PTU):

1. Demonstrate operation of the thermostatic control system by using the PTU.

2. Verify the sequence of capacity modulation, as applicable, and system pump-down.

3. Record the system refrigerant charge and the refrigerant condition (wet or dry) in liquid sight glasses.

4. Correct abnormal conditions and repeat the associated test.

15.14.1.6 Headlight and Stoplight Adjustments

Aim and adjust the headlights and stop lights on each vehicle to meet the specified requirements.

15.14.1.7 Friction Brake

Perform a functional test of the friction brake system. Tests shall include the following, as a minimum:

1. Verification of brake cylinder pressure settings

2. Control and indicator verification

3. System leakage tests

4. Response to dynamic brake feedback signals

5. Functional test of the brake fault detection system

15.14.1.8 Communication Systems

Functionally test all equipment and systems specified in Section 13, Vehicle Communication Systems, to verify conformance with specified requirements. In addition, perform the following tests:

1. Test the PA system, APIS and each PEI for clarity (intelligibility) of voice transmission and reception.

2. Test APC to verify accuracy of the system.

3. Test the CCTV and exterior side view CCTV to verify proper positioning of cameras.

4. Test communication systems not tested at the Contractor's Facilities:

   a. Radio

   b. GPS

c. Vehicle Wireless Communication to Wayside

d. AVL

e. Traffic Light Priority

f. Onboard Public World Wide Web Access, Wireless Data Link

15.14.1.9 CBTC System

Comply with the following:

1. Perform all CBTC self-diagnostic test to ensure system is in a functioning ready-to-run state.

2. Perform calibration procedures, as required by the OEM, prior to dynamic vehicle testing.

15.14.2 Vehicle-Level Dynamic Routine Tests at SEPTA's Facilities

15.14.2.1 General

After completion of all vehicle-level static routine tests and vehicle-level type tests conducted at SEPTA's facilities, perform the following vehicle-level dynamic routine tests on each vehicle at SEPTA's facilities and on the Project alignment.

1. Successful completion of testing is a condition of Acceptance of each vehicle.

2. Instrumentation for the vehicle-level dynamic routine tests shall be as specified for vehicle-level dynamic type tests, as specified above.

SEPTA may elect to use this period to qualify Transportation Department staff.

15.14.2.2 Joint Inspection

Before starting dynamic routine testing, jointly inspect the vehicle with SEPTA. Make adjustments, repairs, or replacements as required for proper operation or as deemed necessary by SEPTA.

15.14.2.3 Vehicle Performance Test

Demonstrate, by dynamic testing on the Project alignment, that each vehicle's tractive power, dynamic braking, friction braking, track braking, and CBTC systems meet the criteria used for the Vehicle Dynamic Type Tests.

1. Test the vehicles only at AW0.

2. If adjustments are required to obtain values corresponding to the required performance levels, make adjustments before formal delivery and note in the vehicle's history book.

15.14.2.4 Burn-In Test

Perform burn-in test:

1. Sequence: Perform after successful completion of the vehicle performance test.

2. Test:

    a. Operate each vehicle a minimum 160 km (100 mi) on the Project alignment in simulated revenue service.

    b. Stop at each station and cycle the doors on both sides of the vehicle.

    c. During the test there shall be no failures, using the same criteria as that used for Reliability in Section 2, Design and Performance Criteria.

3. Retest: If a failure occurs, correct the problem and restart test.

4. Failures or other incidents requiring attention that occur near the end of this period may be considered cause to extend the test period until the Engineer is confident that the vehicles are sufficiently "burned in" and trouble free. This criteria applies to both the City Division and the Suburban Division

5. Successful completion is a condition of Conditional Acceptance.

15.15 Cooperation with SEPTA and Other Systems

Assist SEPTA as necessary in operation of the vehicle(s) for systems integration testing, including but not limited to interface with the Shop, OCS, substations, signal system, track, and wayside.

15.16 Final Inspection and Commissioning Testing

Final vehicle inspection and release to commissioning site shall not be permitted until functional testing is completed and successful.

15.17 Contract Deliverables Requirements List (CDRL)

Comply with the following:

1. Type tests: Submit a test procedure and test report for each.

2. Component routine tests: Submit the manufacturer’s routine test procedure for each. Include routine test reports with the shipping documents or furnish separately to verify that the tests were performed successfully.

3. Vehicle-level routine test: Submit a test procedure and test report.

4. For CDRLs for which both a test procedure and a test report is required, submit test procedures and test reports using the appropriate CDRL number followed by "P" for procedure and "R" for test report, such as CDRL 15-12.P and CDRL 15-12.R.

5. For test reports where multiple vehicles are tested, submit a separate test report for each vehicle, and include the vehicle designator in the CDRL number, such as CDRL 15-41.R/302.

Submit the following in accordance with Section 20, Program Control and Quality Assurance.

15-1 Master Test Plan

15-2 EMI/EMC Component Type Tests
15-3 Cab and Floor Heater Type Tests
15-4 AC Traction Motor Type Test
15-5 AC Auxiliary Motor Type Test
15-6 Low-Voltage DC Motor Type Test
15-7 Traction Gear Unit Type Test
15-8 Auxiliary AC Inverter Type Test
15-9 DC LVPS and Battery Charger Type Test
15-10 Tow Bar and Draft Gear Type Test
15-11 Apparatus, Hoses, Air Lines Cables Clearance Type Tests
15-12 Truck Frame Type Test
15-13 Wheel Equalization Type Test
15-14 Pantograph Type Test
15-15 Traction Inverter Type Test
15-16 Not Used
15-17 Dynamic Brake Resistor Type Test
15-18 Inductor Type Test
15-19 Door Operator Type Test
15-20 Vehicle-Shell Structural Type Tests
15-21 Floor and Roof Assembly Fire Performance Type Test
15-22 Propulsion Combined Type Test
15-23 Friction Brake System Type Test
15-24 Auxiliary Power System Type Test
15-25 Truck Assembly Type Test
15-26 Door System Type Test
15-27 Bridge Plate System Type Test
15-28 Unitized HVAC System Type Test
15-29 Floor Heat System Type Test
15-30 Cab Controls System Type Test
15-31 Communication Systems Type Test
15-32 Network Type Tests
15-33 Monitoring and Diagnostic System Type Test
15-34 CBTC System Type Test
15-35 Low-Location Exit Path Marking Type Test
15-36 Vehicle-Level Static Type Tests at Contractor’s Facilities
15-37 Vehicle-Level Dynamic Type Tests at Contractor’s Facilities
15-38 Air Conditioning Unit Routine Tests Procedure
15-39 Motor Routine Test Procedure
15-40 Traction Gear Unit Routine Test Procedure
15-41 Pantograph Routine Test Procedure
15-42 Traction Inverter Routine Test Procedure
15-43 Auxiliary AC Inverter Routine Test Procedure
15-44 DC LVPS and Battery Charger Routine Test Procedure
15-45 Battery Routine Test Procedure
15-46 Friction Brake Routine Tests Procedure
15-47 Communication Systems Routine Tests Procedure
15-48 Trainline Electric Connection Head Routine Tests Procedure

15-49 Truck Frame Welds Routine Test Procedure
15-50 Wheel Back-to-Back Routine Test Procedure
15-51 Resistance Routine Tests Procedure
15-52 Vehicle-Level Routine Functional Tests at Contractor's Facilities
15-53 Vehicle-Level Routine Wiring Tests at Contractor's Facilities
15-54 Vehicle-Level Routine Watertightness at Contractor's Facilities
15-55 Cab Controls Routine Test at Contractor's Facilities
15-56 Vehicle-Level Dynamic Routine Tests at the Contractor's Facilities
15-57 Pilot Test Program Documentation
15-58 Propulsion and Braking Dynamic Type Tests at SEPTA's Facilities
15-59 Tow Bar Dynamic Type Test at SEPTA's Facilities
15-60 Load Leveling Dynamic Type Test at SEPTA's Facilities
15-61 Load Compensation Dynamic Type Test at SEPTA's Facilities
15-62 Ride Quality Type Test at SEPTA's Facilities
15-63 Noise and Vibration Type Test at SEPTA's Facilities
15-64 EMI/EMC Dynamic Type Tests at SEPTA's Facilities
15-65 CBTC Static and Dynamic Type Tests at SEPTA's Facilities
15-66 Collision Avoidance System Dynamic Type Test at SEPTA's Facilities
15-67 Vehicle-Level Static Routine Tests at SEPTA's Facilities
15-68 Vehicle Performance Test at SEPTA's Facilities
15-69 Burn-In Test at SEPTA's Facilities
15-70 Software and Firmware Security Assessment
15-71 Penetration Testing

15.18 CDRL Details

15-1 Master Test Plan:

1. Submit within 180 days after NTP.
2. Include each test, whether specifically referenced in this Section or located in another section of the Specifications.
3. Include a proposed schedule and location for each test.

15.19 Referenced Standards

The following standards are referenced in this Section:

AAR M-1001	Specifications for Design, Fabrication and Construction of Freight Cars
AHRI Standard 700	Specifications for Refrigerants
ANSI/ASHRAE Standard 37	Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment
ANSI S3.2	Method for Measuring the Intelligibility of Speech over Communication Systems

APTA PR-E-S-013-99	Standard for Emergency Lighting System Design for Passenger Cars
APTA PR-M-S-018-10	Powered Exterior Side Door System Design for New Passenger Cars
APTA RT-S-VIM-020-10	Emergency Lighting System Design for Rail Transit Vehicles
APTA RT-VIM-S-022-10	Low-Location Exit Path Marking
ASME RT-1	Safety Standard for Structural Requirements for Light Rail Vehicles
ASTM D3363	Standard Test Method for Film Hardness by Pencil Test
ASTM D5402	Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs
ASTM E119	Standard Test Methods for Fire Tests of Building Construction and Materials
ASTM E165/E165M	Standard Practice for Liquid Penetrant Examination for General Industry
ASTM E709	Standard Guide for Magnetic Particle Testing
AWS D1.1/D1.1	Structural Welding Code - Steel
EN 50121-3-1	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Train and complete vehicle
EN 50121-3-2	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus
EN 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
IEC 60268-16	Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index
IEC 60349	Electric traction - Rotating electrical machines for rail and road vehicles
IEC 60349-2	Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic converter-fed alternating current motors
IEC 60494-2	Railway applications - Rolling stock - Pantographs - Characteristics and tests - Part 2: Pantographs for metros and light rail vehicles
IEC 60623	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells
IEC 61287-1	Railway applications - Power convertors installed on board rolling stock - Part 1: Characteristics and test methods

IEC 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
IEEE Std 16	Standard for Electrical and Electronic Control Apparatus on Rail Vehicles
ISO 2631	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration
ISO 3095	Acoustics -- Railway applications -- Measurement of noise emitted by railbound vehicles
ISO 3381	Railway applications -- Acoustics -- Measurement of noise inside railbound vehicles
NAS 410	NAS Certification and Qualification of Nondestructive Test Personnel
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems
SMP 800-C	Toxic gas generation from material combustion/Bombardier
UMTA-MA-06-0153-85-6	Conductive Interference in Rapid Transit Signaling Systems Volume II: Suggested Test Procedures

END OF SECTION

Table of Contents

Table of Tables

16.1 General

16.1.1 Scope

This Section defines the minimum performance requirements for materials to be used in the construction of vehicles, and establishes minimum guidelines for workmanship.

It identifies mandatory government requirements and industry specifications controlling the quality of specific materials and components and the construction methods. Alternatives may be considered by SEPTA, if proposed.

Inclusion of a material or product in this section does not imply **approval** of its use in a particular application. Refer to other Sections for detailed requirements for specific vehicle systems.

16.1.2 Quality

Ensure that equipment, materials, manufacturing, assembly, and installation processes and practices are in full conformance with the requirements of the Specifications as well as with proven and recognized industry practices and recommendations.

16.1.3 Standards

Materials and workmanship shall conform to the appropriate industry standards for use on rail transit equipment:

1. These standards include Federal or Military specifications or standards, the specifications and standards of the Aluminum Association, AAR, ANSI, ASME, ASNT, ASTM, AWS, FRA, IEEE, IEC, EN, NACE, NFPA, SSPC, or other requirements as specified in this Section.
2. Foreign or international standards may be proposed as alternatives.
   a. Submit proposed standards in English with a detailed clause-by-clause comparison for review and **approval**.
   b. Use of an alternative standard or standards will require use of all subsidiary or complementary standards in the same system.
   c. A service history of equipment built to these standards may be included to demonstrate the applicability of the standard.

16.1.4 Material Availability in the U.S.

16.1.4.1 Cleaning Agents

Comply with the following:

1. For each part of the vehicle that is normally cleaned, materials proposed for use in that area shall have a manufacturer-recommended cleaning agent available and not prohibited in the US.

2. Cleaning agent information shall also be included in the maintenance documentation for the vehicle.

3. The Contractor shall make every effort to minimize the number of different cleaning agents proposed.

4. Where possible, the recommended cleaning agents shall be among those currently used and approved for similar applications.

5. The following materials are currently used by SEPTA in the cleaning of its existing commuter rail cars with the SEPTA Class and Lot number identified where issued. All car surfaces and equipment, which can be exposed to such products, shall be unaffected by them.

   a. Exterior Vehicle 1) Fine Organics # FO477 car wash acid (67-00404A)

   b. Interior Vehicle 1) ZEP Venture Cleaner 2) Fine Organics #1168 Seat Cleaner 3) Instant Gum Remover (67-02650) 4) ZEP #143 stainless steel polish (67-02491)

   c. Graffiti Remover 1) ZEP #311 Graffiti Remover (67-02652) 2) Write Away 3) Neleco Graffiti Remover 4) Chase Products Co. Vandal Mark Remover (67-R0483) 5) Graffiti Remover (67-026751-A)

   d. General Purpose Cleaner 1) ZEP Venture Cleaner 2) Fine Organics #1168 Seat Cleaner 3) 20 Degree Cloudy Ammonia (61-00150) 4) Penetone #169 5) Power-Whistle 12 Wall Cleaner (67-R0466) 6) National Auto Cleaner #26824 - Spray Nine (67-00465

6. Recommendations from CDC or APTA shall be followed regarding anti-microbial cleaning agents.

16.1.4.2 Maintenance Materials

Fasteners, paint, lubricants, and other materials required for maintenance of the vehicles shall be available and not prohibited in the U.S.

16.1.5 Storage of Material

Ship and store equipment and material intended for use in these vehicles such that damage and reduction in life are prevented:

1. These requirements apply to equipment and material at the Contractor's facilities, at SEPTA's facilities, and to capital spare parts.

2. At a minimum, comply with the following:

   a. Protect stored material subject to corrosion using waterproof covers or coatings. Store materials and equipment within environmentally-controlled areas and off the floor or ground.

   b. Store equipment with ports, covers, and other enclosure openings closed to prevent entrance of dirt or moisture.

   c. Clearly mark dated material with the expiration date; material shall not be used beyond this date.

   d. Handle and store material with special handling or storage requirements according to the manufacturer's requirements.

      - For equipment with special storage requirements, include storage and handling instructions with the equipment.
      - Clearly mark and store material with appropriate nomenclature to prevent misapplication.
      - Include instructions on how to prepare equipment for use after long periods of storage, where applicable.

3. Clearly mark rejected material as such and store in a separate area specifically designated for that purpose.

16.1.6 Prohibited Materials

The Contractor is prohibited from using the following materials on the vehicle:

1. Polyvinyl chloride (PVC)
2. Asbestos
3. Cadmium (except for battery)
4. Lead, all applications, including in paint and coatings, except for electronics solder
5. Polychlorinated Biphenyls (PCBs)
6. Carcinogenic materials as listed by current Publication of the American Conference of Governmental Industrial Hygienists (ACGIH):
   a. Where there are materials that contain trace amounts of carcinogenic substances, they shall be clearly identified in the Safety Data Sheet
   b. Exposure to classifications A1, A2, and A3 carcinogens shall be carefully controlled to levels as low as possible below the TLV (Threshold Limit Value) set by the ACGIH
   c. Chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) compounds, including R-22 refrigerant
7. Urethane foams that do not meet flammability, smoke, and toxicity requirements
8. Materials in the List of Highly Hazardous Chemicals, Toxics and Reactives, 29 CFR 1910.119, Appendix A

16.1.7 Material Reporting Requirements

Comply with the following:

1. Whenever a proposed commercial material is not covered by the Specifications or a standard, it is considered a Contract deliverable, in accordance with Section 1, General Topics and

Definitions, and shall be submitted in accordance with Section 20, Program Control and Quality Assurance.

2. Keep on file Safety Data Sheets (SDSs) for chemical materials (paints, solvents, adhesives, etc.) used in the manufacture of the vehicle, and furnish SDS information as requested by SEPTA for any questionable material. SDSs shall comply with 29 CFR Section 1910.1200 (g).

3. Maintain records that trace all materials to their manufacturers and production lots, and help verify compliance with quality standards specified or cited in this Section.

16.1.8 Dissimilar Materials

Dissimilar materials are materials that corrode or otherwise become damaged when in contact with each other.

1. Connection of dissimilar materials is permitted only at permanent connections and with **approved** electrochemical isolation.

2. Electrochemical isolation treatments shall be permanent and not require maintenance or replacement for the life of the vehicle.

3. Dissimilar materials are not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.

16.2 Standards of Workmanship

16.2.1 Workers

Comply with the following:

1. Vehicle components shall be constructed by workers experienced in the appropriate trades.

2. Comply with worker training and supervision requirements included in the manufacturing control requirements specified in Section 20, Program Control and Quality Assurance.

16.2.2 Use of Production Drawings and Procedures

Comply with the following:

1. Production drawings and manufacturing procedures shall be readily available where manufacturing is occurring and shall be used to verify requirements.

2. Comply with requirements in the Manufacturing section of Section 20, Program Control and Quality Assurance, to ensure that production is always using the current revision.

3. Use tooling as defined by the manufacturing procedures.

4. Work not expressly detailed on the production drawings, such as internal standards or documents, shall conform to the minimum standards of workmanship in this Section, and are subject to the same review and **approval** standards as the drawings.

16.2.3 Use of Manufacturing Tools and Interchangeability

Comply with the following:

1. Attachment points in the vehicle and on subassemblies shall be located by jigs, fixtures, laser levels, and similar methods, unless waived by SEPTA, to ensure accurate placement and per-design tolerances.

2. Like components shall be constructed to the same dimensions and tolerances, hole and subassembly locations, materials and finishes, and shall be interchangeable in the vehicle and between vehicles without modification.

16.2.4 Prohibited Practices

The following are strictly prohibited:

1. Cut-to-fit, match drilling, filing, and other hand-fitting practices, unless **approved**. Where such practices appear necessary in construction, perform a prompt review of design and construction methods and implement corrections to avoid these practices, in accordance with manufacturing control requirements specified in Section 20.

2. Modification of OEM or subcontractor equipment, including minor modifications such as replacement of wire terminations.

3. Modification of Contractor equipment without following the **approved** Modification and Configuration Control Manual procedure, as specified in Section 19, Program Control and Quality Assurance.

16.2.5 Metal Fabrication

Comply with the following:

1. In rolled-steel members, camber and sweep, as received, shall not exceed AISC specifications.

2. Flat plates shall be sheared or cut using modern metal-cutting technology such as laser cutting or waterjet cutting.

3. Structural shapes, pipe, and tube shall be cut to length using band saw or cold cut blade saw. Cut to length by handheld torch is prohibited.

4. Holes shall be drilled or die punched. Bolt holes shall not be burned by hand torch. Holes 38 mm (1.5 in) and larger may be cut by modern metal-cutting technology such as laser cutting or waterjet cutting.

5. Spacing of holes on connection plates shall have a tolerance of maximum 0.8 mm (1/32 in).

16.2.6 Machining

Comply with the following:

1. Machine fits shall adhere to ASME B4.1.

2. Surfaces receiving power machine cutting or profiling shall have a surface finish of maximum 0.003 mm (125 microinches) rms.

3. Shafting shall have the ends squared by face-off in an engine lathe.

4. Chamfers shall be machined on shaft edges and at edge of bore of press on parts.

5. Cut edges shall be de-burred.

16.3 Fasteners

16.3.1 General

16.3.1.1 Scope

Fasteners include threaded fasteners, associated nuts, tapping plates, and washers; quick-release fasteners; rivets; and locking pins.

16.3.1.2 Design

Take note of SEPTA's preferences, and comply with requirements:

1. SEPTA's preference is that fasteners conform to inch-standards. However, use of ISO metric standard fasteners will be permitted for suppliers for which using inch-standard fasteners would require a redesign of products. In the Specifications, metric units and standards are followed by inch units and standards in parentheses.

2. SEPTA has a strong preference for the following:

   a. Fasteners used to mount equipment to the vehicle: Metric.

   b. Fasteners used internal to equipment: Metric- or inch-standard, but not mixed.

3. The Contractor shall select fastener types, sizes, styles, lengths, materials, grades, and finishes that will satisfy the requirements of the design and meet the requirements of the Specifications.

4. Minimize the number of different sizes and styles of fasteners used.

16.3.1.3 Material

Comply with the following:

1. Bolts, screws, nuts, washers, and other related fastening devices shall be plated steel or stainless steel.

2. Aluminum fasteners are generally prohibited except where indicated otherwise in the Specifications.

3. Except for fasteners internal to electrical or electronic components, plastic screws, bolts, nuts, or other plastic fastening components shall not be used unless specifically **approved**.

16.3.1.4 Plating

Comply with the following:

1. Carbon steel, alloy steel, and martensitic stainless steel fasteners shall be plated with zinc, unless specifically waived by SEPTA. Zinc plating shall conform to ASTM B633, Type II, and SC2, SC3, or SC4.

2. Plating materials other than zinc, and plating of any type on high strength fasteners, are subject to **approval**.

3. Cadmium plated fasteners are not permitted.

16.3.1.5 Prohibited

The following are prohibited:

1. Protruding screws, mounting bolts or similar items on the vehicle interior or exterior, except for those appointments that cannot be built into the structure in any other manner.

2. Self-drilling and self-tapping screws, except where specifically **approved**.

3. Tapped holes in structure, brackets, and other vehicle assemblies. Tapping plates shall be used when installing fasteners into vehicle structure or subassemblies.

4. Fasteners installed into blind holes, unless specifically **approved**.

5. Thread-sealing compounds, except for anti-vibration treatments (such as Loctite) where **approved**.

6. Use of elastic stop nuts for electrical connections.

16.3.2 General Requirements for Threaded Fasteners

16.3.2.1 Head Types

Comply with the following:

1. General: Hex heads or hex socket-heads.

2. Where specified: Anti-tamper designs, of the same design throughout.

3. Prohibited: Philips, flat head, or other designs, except in small electronic assemblies or where specifically **approved**.

16.3.2.2 Identification

Comply with the following:

1. Metric fasteners: Shall be identified as required by applicable ISO standards.

2. Inch fasteners: Shall be identified as required by applicable U.S. standards.

16.3.2.3 Maintenance Access

Provide access for maintenance or replacement of threaded fasteners and nuts. When bolts are used to secure equipment where the bolt head is inaccessible, provide a reusable mechanical locking device to prevent the bolt head from turning when the nut is being turned.

16.3.2.4 Thread Projection

Comply with the following:

1. Minimum projection: 1-1/2 full screw threads beyond the nut, at proper torque.
2. Maximum projection:
    a. With elastic stop nuts: 6.4 mm (1/4-inch), regardless of bolt diameter.
    b. Without elastic stop nuts:
        - 6.4 mm (1/4 in) diameter or less: 1-1/2 full threads plus 6.4 mm (1/4 in)
        - Greater than 6.4 mm (1/4 in) diameter: Eight full threads, unless otherwise **approved**.

16.3.2.5 Bolt Hole Size

Bolt hole clearances shall not exceed the recommendations of ISO 273 (or Industrial Fasteners Institute).

16.3.2.6 Tapping Plates

If tapping plates are used, comply with the following requirements:

1. Minimum Thickness: Equal to diameter of the bolt for which the tapping plate is intended.
2. Strength: Same standards as the equivalent nut.
3. Installation:
    a. Attach to the structure with mechanical fasteners unless otherwise **approved**.
    b. Drill a clearance hole in the structure for the bolt.

16.3.3 Special Requirements for Structural Fasteners

16.3.3.1 Scope

This section applies to structural and load carrying bolts:

1. It includes structural bolts for under-vehicle and roof equipment.
2. It includes fasteners used on the side sill to attach heavy equipment brackets (these are considered structural fasteners).

16.3.3.2 Material and Property Class (or Grade)

Comply with the following:

1. Structural or load-carrying bolts shall be medium carbon steel.
2. Metric (or inch) bolts and nuts shall conform to minimum requirements as indicated in the table below, including markings. Stronger fasteners shall be used if required for the application.
3. Nuts shall have a material proof strength equal to or greater than the material ultimate tensile strength of the fastener with which it is used. For applications where this is not achievable, submit specific calculations showing that the nut is stronger than the bolt to prevent undetected internal thread stripping.

TABLE 16-1, STRUCTURAL OR LOAD CARRYING BOLTS: MINIMUM GRADE		
	Standard	**Property Class (Grade)**
Bolts	ISO 898-1 (SAE J429 or ASTM A449)	8.8 (5)
Nuts	ISO 898-2 (SAE J995)	According to bolt strength

16.3.3.3 Minimum Size

Bolt diameter shall be minimum 10 mm (3/8 in), regardless of design load.

16.3.3.4 Required Documentation

Comply with the following:

1. Structural fasteners shall have documentation available for examination by SEPTA at the Contractor's QA department:
    a. Identification of manufacturer
    b. Purchase specifications
    c. Fastener material or grade
    d. Finish, including plating material and specifications, when applicable
2. Obtain and hold the documentation for a period not ending before three years after expiration of the last vehicle's warranty period, whether the buyer is a subcontractor, supplier, or the Contractor.

16.3.3.5 Additional Requirements for Safety-Related Fasteners

Comply with the following requirements for safety-related fasteners:

1. Scope:

    a. Safety-related fasteners include, but are not limited to, those applied to trucks, bolsters, brake equipment, couplers, and power collection devices.

    b. A fastener is safety related if failures cannot be tolerated; that is, if even a single fastener fails, there is a possibility of brake failure, derailment, or accident.

    c. In the event of a dispute, SEPTA will make the final determination of which fasteners are safety related.

2. Testing for Conformance to Purchase Specifications:

    a. Have a representative sample of each production lot of fasteners tested for conformance to purchase specifications by an independent laboratory accredited by the American Association of Laboratory Accreditation (AALA), or **approved** equal.

    b. A production lot is defined as one size of fastener, from one manufacturer, and produced during one continuous production run. Fasteners not meeting this definition of production lot shall be treated as separate lots.

    c. Testing shall be performed using sample quantities as proposed and **approved**.

    d. Tests conducted shall confirm that fastener material meets specified chemistry and strength requirements.

    e. Obtain certified test results from the testing laboratory and hold the documents for a period not ending before three years after expiration of the last vehicle's warranty period.

3. Testing for Hydrogen Embrittlement:

    a. Safety-related fasteners that are plated or chemically cleaned shall have certification of hydrogen-embrittlement testing.

    b. The certification shall be based on a representative sample of actual production fasteners that have been tested by the original equipment manufacturer, Contractor, or a supplier for hydrogen embrittlement following SAE USCAR7-1 procedures. The plating process shall be certified to ASTM F519 procedures.

    c. An ASTM F606/F606M wedge-test sample may be used in place of the ASTM F519 standard samples.

    d. Test loads shall be a minimum of 80% of yield strength or proof load and held for a minimum of 168 hours. Any failures shall result in the rejection of the entire lot.

    e. Obtain certified test results from the testing laboratory and hold the documents for a period not ending before three years after expiration of the last vehicle's warranty period.

16.3.4 Coatings other than Zinc

Comply with the following requirements for alternate fastener coatings (other than zinc):

1. Alternate fastener coatings are permissible only if **approved**. If **approved**, they shall be qualified by testing per ASTM B117 with no red rust or visible corrosion products after 96 hours of exposure.
2. Test for hydrogen embrittlement in accordance with the Testing for Hydrogen Embrittlement section, above, as specified below:
    a. Fasteners less than Property Class 8.8 (or Grade 5): If the coating has the possibility of causing hydrogen embrittlement, each lot shall be tested for hydrogen embrittlement.
    b. Fasteners of Property Class 8.8 (or Grade 5) or higher: Each lot shall be tested for hydrogen embrittlement regardless of the coating's propensity for hydrogen embrittlement, including OEM plated zinc or yellow bolts.
3. If the proposed coating results in a change in the K-value for the plated fastener to outside the range of 0.13-0.15, as defined by IFI-543, comply with the following:
    a. Use the alternate coating on all fasteners within the particular LRU.
    b. Provide an indelible label identifying the coating type used within the LRU and the required torque values for each size fastener used.
    c. Fasteners internal to a subcomponent within an LRU may use the standard coating system if they are not subject to removal during maintenance activities.

16.3.5 Self-Locking Nuts and Washers

16.3.5.1 Self-Locking Nuts

Comply with the following:

1. Self-Locking Nut Requirements:
    a. Type: Prevailing-torque, nylon-insert type, regular-height, self-locking ESNA stop nuts, or **approved** equal.
    b. Alternate type: All-metal; use only where there is insufficient clearance to install ESNA type lock nuts, or where the lock nut is exposed to temperatures above manufacturer's recommended maximum temperature.
    c. Standard: Conform to IFI ISO Standards Handbook (or inch fastener standards found in the IFI Inch Fastener Standards Book) or NASM21044.
    d. High Temperature: Nylon insert lock nuts shall not be used near heat sources that will exceed the lock nut manufacturer's recommended maximum temperature.
2. Use Requirements:
    a. Self-locking nuts (lock nuts): Use throughout, where appropriate for the application.

b. Non-self-locking nuts with lock washers: Use only in nonstructural applications upon **approval**, or where required by the Specifications.

16.3.5.2 Washers

Comply with the following:

1. Washer Requirements:

    a. Suitable for the application and matched with the property class (or grade) of the bolt with which it is used.

    b. Where high-strength fasteners (above Class 8.8/Grade 5) are applied, washers shall be hardened.

    c. Washers shall comply with ISO standards found in the Industrial Fasteners Institute (IFI) ISO Standards Handbook (or inch fastener standards found in the IFI Inch Fastener Standards Book).

    d. If used, lock washers, shall conform to IFI standards.

2. Use Requirements: Provide washers under the heads of bolts and under nuts.

3. Use Restrictions:

    a. Split-ring lock washers are prohibited except where specifically **approved**.

    b. Lock washers shall not be used in structural applications or in fatigue applications where the fastener must be torqued and marked. If applicable, prevailing torque nuts shall be used for these applications.

    c. Other types of washers, including Belleville washers, may be used for special applications with **approval**.

16.3.6 Torqueing

Comply with the following requirements for torqueing:

1. Specify fastener torque value on the production drawings and manufacturing procedures.

2. Threaded fasteners shall be torqued to the value assigned by the designer or to standard torque values recommended by the fastener manufacturer as appropriate to the application.

3. Torque safety-related fasteners to a minimum preload equal to 75% of their proof load, including truck and brake equipment bolts and all fasteners exposed to fatigue loads, and then “torque stripe” by paint or other **approved** means.

4. Calculate fastener installation torque for standard oiled or waxed bolts with standard or heavy hex nuts from Industrial Fasteners Institute equations in "Torque Book for Fasteners." Use the following values for coefficient of friction, "K", unless another coefficient of friction was established during qualification of an alternate thread plating or coating:

    a. Unplated threads: K = 0.18

    b. Plated threads: K = 0.15

5. Torque self-locking nuts in accordance with their manufacturer's recommendations or conduct tests to determine the proper installation torque.

6. Perform torqueing only by calibrated torque wrench.

7. For those nuts or bolts requiring "torque striping," SEPTA may require bolt torque-tension tests to verify that installed preload is equivalent to 75% of proof loads.

16.3.7 Other Fasteners

16.3.7.1 Quick-Release Fasteners

Quick release fasteners may be quarter-turn type or other types, as **approved**:

1. Quarter-turn fasteners:

    a. Shank diameter: Minimum 6.35 mm (1/4 inch)

    b. Strength: Adequate for the application

    c. Manufacturer: Southco, or **approved** equal

2. Head type: Philips, tamper proof, hex socket, or hex head.

16.3.7.2 Rivets and Lock Pins

Rivets and lock pins shall meet the following requirements:

1. Exposed to passengers: Austenitic stainless steel or aluminum as appropriate to the materials being joined.

2. Exposed heads: Concentric with the shank and free from rings, fins, pits, and burrs.

3. Structural steel rivets: Conform to ASTM A502.

4. Swage-locking (Huckbolt-type) fasteners: Conform to MIL-P-23469.

Installation:

1. Rivets:

    a. Driven hot: May be hand driven and shall completely fill the rivet holes.

    b. Driven cold: Shall be mechanically driven.

c. Removed and replaced: Ream holes to the size required such that the next larger rivet may be driven securely.

2. Huckbolt-type fasteners:

   a. Machine or grind smooth rough surfaces of the collar end where accessible to passengers, crew, or maintenance personnel performing routine maintenance functions.

   b. SEPTA will make the final determination whether an application is hazardous to maintenance personnel.

16.3.8 Location- and Application-Specific Fastener Requirements

16.3.8.1 Interior – Exposed to Passengers

Comply with the following requirements:

1. Install such that the fastener head is flush with the mating surface.

2. Match the surfaces being joined using bright or finished fasteners:

   a. General use: Austenitic or plated martensitic stainless steel.

   b. For stanchions: Austenitic grade stainless steel.

3. Use screws, bolts, and nuts only if specifically **approved**.

16.3.8.2 Exterior – Exposed to Passengers

Comply with the following requirements:

1. Stainless steel vehicle body: Austenitic stainless steel.

2. Aluminum vehicle body: Austenitic stainless steel or aluminum alloy fasteners, as appropriate to the design and appearance requirements.

16.3.8.3 Access Required

For access panels, equipment box covers, or other areas requiring access, comply with the following:

1. Fasteners shall be captive to the panel or cover in which they are used.

2. Where Operator or maintenance access is expected more often than every five years, provide quarter-turn fasteners or similar quick-release fastener. Where greater clamping force is required, such as for EMI containment, alternate fasteners may be proposed.

3. Where accessible to passengers, provide tamper-resistant type fasteners of a single style.

16.3.8.4 Heat Producing Equipment

When making connections to heat producing equipment, take into consideration the thermal expansion of the components for selection of fastener materials:

1. If the joined components are high-expansion alloys such as copper or austenitic stainless steel, use austenitic stainless steel fasteners.
2. If the joined components are low-expansion materials such as carbon steel or ferritic stainless steel, use zinc plated carbon steel fasteners of minimum Class 8.8 (or Grade 5).
3. Cadmium plated fasteners are not permitted.
4. Use only fasteners rated by fastener manufacturer for maximum ambient temperatures.

16.4 Joining

16.4.1 Joint Fitting

Comply with the following:

1. Joints shall be properly fitted, whether exposed or concealed.
2. Gaps between joints shall be held to a minimum and be uniform in width.
3. The edges of panels shall have a smooth, finished appearance.

16.4.2 Metal-to-Metal Connections

Comply with the following:

1. Metal riveted or bolted to metal:
   a. Contact surfaces shall be free of dirt, grease, rust, and scale.
   b. Coat with an epoxy primer as specified below in the Paints, Graphics, and Coatings section, unless an alternate proposal is **approved**.
2. Aluminum: Metal-to-metal connections shall be as specified below in the Aluminum section.

16.4.3 Wood-to-Metal Connections

Comply with the following:

1. Wood and ferrous metal surfaces joined:
   a. Coat wood with two coats of epoxy paint.
   b. Coat metal with primer, as specified below in the Paints, Graphics, and Coatings section.
2. Bolts or rods passing through wood: Coat with primer.
3. Aluminum: Wood-to-metal connections shall be as specified below in the Aluminum section.

16.4.4 Wood-to-Wood Connections

Wood and wood joined: Coat both abutting surfaces with two coats of epoxy.

16.5 Metal

16.5.1 General

Comply with the following:

1. Apply metallic materials according to their specification properties.
2. Copies of all test reports and mill certificates for sheet, castings, forgings, and extrusions shall be kept on file and are subject to review by SEPTA.
3. Unless otherwise specified as per the specific alloy, test for the following elements, which shall not exceed the percentage limits below:

Unalloyed / Alloy Steel Boundary

Constituent	Al	B	Bi	Cr	Co	Cu	Mn	Mo	Ni	Nb	Pb	Se	Si	Te	Ti	W	V	Zi	Lanthanides	Other*
Percentage	0.10	0.0008	0.10	0.30	0.10	0.40	1.65	0.08	0.30	0.06	0.40	0.10	0.50	0.10	0.05	0.10	0.10	0.05	0.05 each	0.05

* except S, P, C and N

4. Structural components or assemblies are defined as the following:
   a. Components or assemblies subjected to primary loads from the weight of the vehicle or from imposed external forces.
   b. Components or assemblies that could cause a derailment of the vehicle due to failure of that component or assembly.
   c. Parts directly attached to structural components or assemblies by welding or brazing.
5. All other components or assemblies are considered nonstructural.
   a. Welding of nonstructural parts shall be subject to the same requirements as welding of structural parts.

16.5.2 Stainless Steel

16.5.2.1 Austenitic Stainless Steel

Comply with the following:

1. General requirements for delivery:
   a. As required by the Certification Provisions of ASTM A666.

b. Structural applications: Test for susceptibility to intergranular corrosion in accordance with ASTM A262:
   - Practice A: Use to accept material only
   - Practice E: Required for final determination of acceptance or rejection of material that is not acceptable by Practice A.

2. Structural components assembled by fusion or resistance welding:
   a. Specification and composition:
      - AISI type 201L, 301L, 301LN or SUS301L (with Nitrogen), 316L
      - Conform to the requirements of ASTM A666 except that the carbon content shall not exceed 0.03 percent and type 301LN and SUS301L (with Nitrogen) shall not exceed 0.25 percent nitrogen.
   b. Any structural material in which the yield strength exceeds 80% of the tensile strength shall not be used.

16.5.2.2 Ferritic Stainless Steel

Comply with the following:

1. General requirements: As specified in ASTM A240/A240M.
2. Used in welded construction:
   a. May be used only with specific **approval**.
   b. Shall contain stabilizing element(s) to prevent sensitization during welding.
   c. When Charpy V Notch (CVN) impact tested, based on lots, shall have minimum absorbed energy of 27 J (20 ft-lb) at - 29° C (- 20° F).
   d. Shall have a balanced composition (low carbon or suitable titanium content or both) that will, for all conditions of fabrication and assembly into the vehicle body, inhibit formation of martensite and limit chromium depletion in weld heat-affected-zones, such that material meets ASTM A763 requirements for resistance to inter-granular corrosion.
   e. Where ferritic stainless steels are welded to other structural steels, the less-noble steel shall be painted with weld-through primer.

16.5.2.3 Duplex Stainless Steel

Duplex stainless steel may be used only with specific **approval**:

1. General requirements:
   a. As per ASTM A480/A480M
   b. When CVN impact tested, based on lots, shall have minimum absorbed energy of 27 J (20 ft-lb) at -29° C (-20° F)

2. Structural applications:

    a. Test for susceptibility to intergranular corrosion in accordance with ASTM A923:

        - Practice A: Use to accept material only.
        - Practice C: Required for final determination of acceptance or rejection of material that is not acceptable by Practice A.

    b. Where duplex stainless steels are welded to other structural steels, paint the less-noble steel with weld-through primer.

16.5.2.4 Other Stainless Steel

Other stainless steels, non-welded applications: ASTM A666 is acceptable.

16.5.2.5 Testing

Before purchasing, submit a test and inspection plan that verifies that the stainless steel conforms to specified requirements, as described in the Contract Deliverables Requirements List (CDRL), below.

16.5.3 Carbon and High-Strength Low-Alloy (HSLA) Steel

Comply with the following:

1. Application: Submit a CDRL identifying steel grades and application for structural shapes, plates, and bars.

2. HSLA product forms:

    a. HSLA structural product forms shall contain alloying additions sufficient to have a corrosion index of 6.0 or higher, as calculated by ASTM G101.

    b. HSLA product forms shall be in the same welding group as the HSLA plate, sheet, or strip used in the majority of the structure, per AWS D1.1/D1.1M, Table 3.1, **approved** Base Metals for Prequalified WPSs.

3. Base Metal: Each heat of CWelded carbon and HSLA steel: Shall be tested to confirm 27 J (20 ft-lb) CVN impact strength in the CGHAZ (Coarse grain heat affected zone 1 mm from fusion area) at -18 degrees C (0 degrees F).

4. Application:

    a. Carbon and HSLA steels shall be applied according to their specification properties.

    b. Hot rolled or formed structural shapes conforming to ASTM A36/A36M may be used for nonstructural applications, including equipment supports, jack pads, and clip angles.

5. Testing: Before purchasing carbon and HSLA steel, submit a test and inspection plan that verifies that the carbon and HSLA steel conforms to specified requirements, as specified in the Contract Deliverables Requirements List (CDRL).

6. Other steel standards may be proposed and submitted for **approval**.

16.5.4 Steel and Stainless Steel Castings

16.5.4.1 General

Comply with the following:

1. Application: Submit a CDRL outlining steel and stainless steel casting selection and application.
2. Standards:
    a. Steel castings: Comply with ASTM or AAR specifications.
    b. Stainless steel castings: Comply with AISI, ASTM, or EN/ISO standards.
3. Marking: Apply pattern and serial numbers in a manner that does not impair their strength.
4. Disposal of Nonconforming Castings: If castings are found to be nonconforming to requirements determined by the design qualification castings, the material shall be repaired, retested, and re-inspected or destroyed at the Contractor's expense.
5. Welding of castings: Permitted, if the casting supplier performs repair welds in accordance with **approved** written procedure(s) and welders are qualified to ASTM A488/A488M.

16.5.4.2 Design Qualification

Comply with the following:

1. Before castings are produced: Select acceptance levels for the design qualification radiographic examinations as appropriate for the service intended, subject to **approval**.
2. Qualification Test:
    a. Conduct on one casting, selected by SEPTA from the first lot of production castings, to test the casting design:
        - Perform radiographic examination to determine material soundness using reference radiographs to ASTM E446, and mechanical testing, as required.
        - Radiographs shall meet the requirements of ASTM E94/E94M and ASTM E1030/E1030M and the quality level in the area of inspection shall be at least 2% (2-2T).
        - Radiographs resulting from the Qualification Test shall be made available to SEPTA for review.
        - Perform nil-ductility brittle transition testing (DBTT) at - 24° C (-11° F) from sections of the casting as agreed with SEPTA.

    b. Submit a Qualification Test report as specified in the Contract Deliverables Requirements List (CDRL) section, below. Obtain **approval** before production of castings.
3. After Qualification: Once a design is qualified and **approved**, no changes shall be made in the casting pattern, technique, heat treatment, material composition, or casting location without re-qualification in accordance with the requirements of this Section.

16.5.4.3 Quality

Comply with the following:

1. Quality shall be equal to or better than the design qualification castings in all respects.
2. Test, inspect, and accept castings in accordance with procedures described in AAR M-201.
3. Perform the inspections below and furnish a test report for each lot of castings produced:
    a. Magnetic particle inspections (steel and ferritic stainless steel castings):
        - Conduct on all surfaces of each casting according to ASTM E709. Testing personnel shall be certified to NAS 410, ASNT SNT-TC-1A, or ANSI/ASNT CP-189.
        - Structural castings, including coupler castings: Maximum permissible magnetic particle indications shall be 6 mm (1/4 in) in the direction transverse to the usual direction of loading, and 19 mm (3/4 in) in the direction parallel to the usual direction of loading.

    b. Dye-Penetrant Testing (austenitic and duplex stainless steel castings):
        - Conduct on all mating surfaces, high-stress areas, and tapped holes.
        - Testing personnel shall be certified to ASNT SNT-TC-1A or ANSI/ASNT CP-189.

    c. Radiographic inspection:
        - Shall not exceed Severity Level 3 of ASTM E446 in critical areas and shall not exceed Severity Level 5 in other areas of the castings.
        - Sampling frequency:
            - 100% of the first two castings.
            - 50% of the next four castings.
            - 25% of the next eight castings
            - After severity levels have been proved, 1 casting out of each 10 produced.
            - If none of the first 100 castings are rejected by radiographic inspection, 1 casting out of each 25 produced.
            - If an unacceptable casting is found during sampling, Contractor shall inspect 100% of other castings from the lot/heat, or before and after in sequence (if sequentially cast), until the extent of the unacceptable condition(s) is determined.
            - If the reason for the failure has been isolated, based upon SEPTA’s review, sampling may return to the immediately previous frequency until the severity levels are again proved.
            - Any change in foundry, casting tooling, or casting process shall return the sampling back to 100%.

16.5.4.4 Specific Applications

Comply with the following in the specified application:

1. Truck and vehicle-body structures:
   a. Meet AAR M-201, Grade "B", plus 2% nickel, minimum.
   b. Heat-treat castings to develop the following:
      - Minimum tensile strength: 517 MPa (75 ksi)
      - Minimum yield strength: 331 MPa (48 ksi)
      - Elongation: Minimum 25% in 50.4 mm (2 in)
      - Reduction of area: Minimum 50%
2. Truck side frames and bolsters:
   a. Comply with applicable standards:
      - Bolsters: AAR M-202
      - Side frames: AAR M-203
3. Coupler, drawbars, and anchors: Meet AAR Specification M-201, Grade "C", quenched and tempered.

16.5.5 Cast Iron

16.5.5.1 General

Comply with the following:

1. Application: Submit a CDRL outlining cast iron selection and application. Grey cast iron castings shall not be used for structural components.
2. Standards:
   a. Ductile Iron Castings: Comply with ASTM A874/A874M.
   b. Grey Iron Castings: Comply with ASTM A48/A48M.
3. Marking: Apply pattern and serial numbers in a manner that does not impair their strength.
4. Disposal of Nonconforming Castings: If castings are found to be nonconforming to requirements determined by the design qualification castings, the material shall be repaired, retested, and re-inspected or destroyed at the Contractor's expense.
5. Welding of Castings:
   a. Grey iron castings: Prohibited except for repair welding of casting defects at the original casting foundry.

b. Ductile iron castings: May be welded to repair casting defects if permitted by the material specification. The casting supplier must perform repair welds in accordance with specification requirements, using **approved** written procedure(s) and welders qualified to ASTM A488/A488M.

c. Castings supplied in the heat-treated condition shall be heat treated after completion of all repair welding.

d. Welding shall not be used to attach iron castings to other parts of the vehicle, including other castings.

16.5.5.2 Design Qualification

Comply with the following:

1. Before castings are produced: Select acceptance levels for the design qualification radiographic examinations as appropriate for the service intended, subject to **approval**.

2. Qualification Test:

    a. Conduct on one casting, selected by SEPTA from the first lot of production castings, to test the casting design:

    - Perform radiographic examination to determine material soundness using reference radiographs to ASTM E446, and mechanical testing, as required.
    - Radiographs shall meet the requirements of ASTM E94/E94M and ASTM E1030/E1030M and the quality level in the area of inspection shall be at least 2% (2-2T).
    - Radiographs resulting from the Qualification Test shall be made available to SEPTA for review.

    b. Submit a Qualification Test report as specified in the Contract Deliverables Requirements List (CDRL) section, below. Obtain **approval** before production of castings.

3. After Qualification: Once a design is qualified and **approved**, no changes shall be made in the casting pattern, technique, heat treatment, material composition, or casting location without requalification in accordance with the requirements of this Section.

16.5.5.3 Quality

Comply with the following:

1. Quality shall be equal to or better than the design qualification castings in all respects.

2. Test, inspect, and accept castings in accordance with procedures described in AAR M-201.

3. Perform the inspections below and furnish a test report for each lot of castings produced:

    a. Magnetic particle inspections:

    - Conduct on all surfaces of each casting according to ASTM E709. Testing personnel shall be certified to NAS 410, ASNT SNT-TC-1A, or ANSI/ASNT CP-189.

- Structural castings: Maximum permissible magnetic particle indications shall be 6 mm (1/4 in) in the direction transverse to the usual direction of loading, and 19 mm (3/4 in) in the direction parallel to the usual direction of loading.

b. Radiographic inspection:

- Shall not exceed Severity Level 3 of ASTM E446 in critical areas and shall not exceed Severity Level 5 in other areas of the castings.
- Sampling frequency:
    - 100% of the first two castings.
    - 50% of the next four castings.
    - 25% of the next eight castings.
    - After severity levels have been proved, 1 casting out of each 10 produced.
    - If none of the first 100 castings are rejected by radiographic inspection, 1 casting out of each 25 produced.
    - If an unacceptable casting is found during sampling, Contractor shall inspect 100% of other castings from the lot/heat, or before and after in sequence (if sequentially cast), until the extent of the unacceptable condition(s) is determined.
    - If the reason for the failure has been isolated, based upon SEPTA's review, sampling may return to the immediately previous frequency until the severity levels are again proved.
    - Any change in foundry, casting tooling, or casting process shall return the sampling back to 100%.

16.5.6 Aluminum

16.5.6.1 General Requirements

Comply with the following:

1. Aluminum-alloy mill products:

    a. Identify by designations prescribed by the Aluminum Association.

    b. Conform to specifications contained in the Aluminum Association's publication "Aluminum Standards and Data."

2. Non-structural Castings:

    a. Sand castings: Conform to ASTM B26/B26M.

    b. Die castings: Conform to ASTM B85/B85M.

    c. Permanent mold castings: Conform to ASTM B108/B108M.

3. Structural Castings:

    a. Contractor shall propose an applicable standard and inspection plan for **approval**.

4. Aluminum alloy forgings and extrusions:

    a. Conform to ASTM B247 for forgings and ASTM B221 for extrusions.

    b. Qualification test as follows:

        - Section and etching of flow patterns per ASTM E340
        - Liquid penetrant examination per ASTM E165/E165M
        - Radiographic examination or ultrasonic examination per ASTM E94/E94M and ASTM E1742/E1742M or ASTM B594
        - Static load testing per ASTM B557

5. Aluminum alloy sheet and plate: Conform to ASTM B209/B209M.

16.5.6.2 Design Stresses

Design aluminum structural members such that calculated stresses under the maximum load do not exceed allowable stresses listed in the Aluminum Association's "Aluminum Design Manual."

Make proper allowance for the effects of fatigue, for column and plate stability effects, and for strength reduction at welded regions.

16.5.6.3 Connections to Aluminum

Take specific measures, based on a suitable method that can be adapted to the design involved, to prevent the risk of direct metal-to-metal contact that could result in galvanic or electrolytic corrosion. The measures shall be **approved**. Comply with the following minimum requirements for connections to aluminum unless they conflict with recommendations by the aluminum manufacturer:

1. Provide protection at the contact surfaces of connections to aluminum.

2. Carbon steel and stainless steel fasteners (including washers and nuts):

    a. Shall be zinc plated.

    b. Shall be coated with zinc chromate paste before installation.

    c. Only the head and unthreaded portion of the shank of the bolt shall be in contact with the aluminum part when secured in place, where possible. Suitable bushings may be used in place of the zinc-chromate paste.

3. Comply with the follow requirements for connections to aluminum alloy:

    a. Surfaces shall not be secured to, nor make direct contact with the surfaces of the following:

        - Wood; or

- The following metals:
  - Copper or copper bearing aluminum alloy
  - Brass or bronze
  - Silver
  - Nickel and nickel-plated parts or nickel alloys
  - Tin
  - Ferrous materials

b. Aluminum alloy to aluminum alloy: Protect surfaces of parts by painting with zinc chromate primer before securing.

c. Aluminum alloy to steel:

- Protect with a one-part polysulfide sealant.
- Alternatively, use an **approved** insulation joint material, such as mica, that completely covers the faying surfaces. The material shall be non-hygroscopic and, if fibrous, shall be impregnated with bitumen or some other **approved** water and moisture-repellant substance.
- Prime and paint fasteners with red oxide or aluminum paint after installation.
- Rivets driven hot may be considered as covered by a protective oxide coating due to the heating, but the method of riveting shall, if possible, always be with the formed rivet head in contact with the aluminum alloy.

d. Aluminum alloy with zinc plated stainless or carbon steel fasteners: Protect surfaces as follows:

- Coat with zinc chromate paste or **approved** equal before installation.
- Where possible, only the head and shank of the bolt shall be in contact with the aluminum part when secured in place.
- Suitable **approved** bushings may be used in place of the zinc-chromate paste.

16.5.6.4 Interior Trim

Unpainted aluminum visible to passengers shall have a clear, anodic finish:

1. Standard: Conform to AAMA 611, Schedule AA-M12C22A31
2. Coating thickness: Minimum 10 µm (0.0004 in)
3. Coating weight: Minimum 32 µg/mm^2 (21 mg/in^2)

16.6 Welding and Brazing

16.6.1 General

16.6.1.1 Scope

This section applies both to welding and brazing performed on vehicle structural elements and on equipment and systems provided for use on the vehicle, unless waived by SEPTA.

16.6.1.2 Quality

Comply with the following:

1. Control the quality of welding and brazing, including that performed by subcontractors.
2. Before performing work under this Contract, welders shall be tested to confirm their ability to operate the welding equipment and to make the types of welds required by the design or this document.

16.6.2 Welding and Brazing Prohibitions

The following weld process and material restrictions shall apply in vehicle structure welding:

1. High-iron-powder flux-type rods such as E6024, E7024 and rods known as "jet rod" may not be used.
2. Short-arc MIG welding using hardwire with argon, or argon/CO_2 shielding may be used only on sheet metal, gauges 12 and thinner. Weld sheet steel in accordance with AWS D1.3/D1.3M.
3. Galvanized steel shall not be welded to stainless steel.
4. Brazing shall not be used to join stainless steel to itself or to other metals unless specifically **approved**.

16.6.3 Welding

16.6.3.1 Structural Welding

Comply with the following:

1. Structural welding practices not specifically covered in other sections of the Specifications shall be in accordance with the following AWS standards. Requirements for cyclically loaded structures shall be applied:
    a. AWS D1.1/D1.1M, for steel 3.2 mm (1/8 in) and thicker
    b. AWS D1.2/D1.2M
    c. AWS D1.3/D1.3M, for steel and stainless steel thinner than 3.2 mm (1/8 in)
    d. AWS D1.6/D1.6M

   e. AWS D15.1/D15.1M

   f. AWS Welding Handbook

   g. AWS D17.2/D17.2M, for resistance welding

2. Alternate standards may be proposed for design and welding execution, subject to **approval**. Mixing standards from different standards bodies is prohibited.

3. Other requirements for welding of austenitic stainless steels:

   a. AISI 201L and 301LN stainless steels shall be treated as P-No. 8, Group-No. 3 category for reference to ASME BPVC requirements.

   b. Weld heat-affected zones (HAZ) and weld metal shall be limited to maximum allowable stress values in ASME BPVC-VIII-1, Table UHA-23 for UNS S20100 stainless steel and Table UW-12 rating of welds, regardless of strength level of the base metal.

   c. Ferrite number for welds shall be between WRC 4 and WRC 10, or as proposed and **approved**.

4. Additional information on definitions, processes or other questions pertaining to welding shall be referred to the AWS Welding Handbook.

16.6.3.2 Welding Procedure Qualification

Comply with the following:

1. Welding procedure specifications (WPSs) shall be qualified by the Contractor, accompanied by procedure qualification records (PQRs) containing welding test results, and are subject to **approval**.

2. Use of prequalified WPSs is prohibited unless reviewed and specifically **approved**. WPSs shall be identified on shop drawings specifically for that purpose.

3. WPSs for partial penetration and fillet welds shall reference a PQR using the same essential variables and tested for mechanical properties.

4. CVN specimen impact value: Shall develop 27 J (20 ft-lb) CVN impact strength in the CGHAZ (1 mm from fusion area) at -18 degrees C (0 degrees F).

   a. Take three sample specimens per location.

   b. One test result may be between 20 and 26 J (15 and 19 ft-lb), with the average being greater than or equal to 27 J (20 ft-lb).

5. Perform general welding, not specified elsewhere, in accordance with the standards of AWS D1.1/D1.1M.

16.6.3.3 Welder Qualification and Identification

Comply with the following:

1. Welders shall make only those welds for which they have been qualified in accordance with the following:
   a. Requirements of the AWS or ASME BPVC-IX, qualifying procedures.
   b. Alternate standards may be proposed, subject to **approval**.
2. Make available records of welder qualification tests for review upon SEPTA's request.
3. Stamp critical strength welds with an identifying symbol that can be traced to the welder who performed the work.

16.6.3.4 Weld Type Requirements

Comply with the following:

1. Full penetration welds:
   a. Required for structural welds unless otherwise **approved**.
   b. If made from one side without backup they shall be considered partial penetration welds.
2. Partial penetration welds:
   a. May be used for structural connections only with **approval** of a formal detailed proposal:
      - Furnish design calculations supporting the penetration required
      - Conduct tests to prove that production welding achieves this required penetration with a margin of safety suited to the design application
   b. Prohibited where subject to alternating tensile or bending loads at the weld root.
3. Fillet welds: May be used only to carry shear loads between statically loaded members.

16.6.3.5 Weld Inspection

Comply with the following:

1. Visually inspect each structural weld in accordance with the applicable AWS requirements:
2. First production welds:
   a. Inspect visually in accordance with the specified AWS welding code requirements
   b. Inspect by nondestructive surface inspection methods (dye penetrant or magnetic particle, as appropriate; see Section 15, Testing, for requirements), regardless of whether the assembly was presented for First Article Inspection
3. Specify additional nondestructive inspection requirements for subsequent welds.

4. For full penetration welds, comply with the following:

    a. On the first structure, inspect nondestructively, volumetrically all full penetration welds (ultrasonic or radiographic methods), according to the applicable code or standard.

    b. For subsequent full penetration welds:

        - The proposed test welds shall be selected from among welds that are most critically loaded as decided by calculations or load test results.
        - With **approval**, destructive sectioning and metallurgical examination may be substituted for some or all of the required volumetric inspection requirements for production welding.
        - The inspection sampling plan shall, at a minimum, meet the following:
            - 100% of the first assemblies and related subassemblies
            - 50% of the next four assemblies and related subassemblies
            - 25% of the next eight assemblies and related subassemblies
            - After severity levels have been proved, 1 welded assembly and related subassemblies out of each 10 produced
            - If unacceptable welds are found, then all of previous welded assemblies up to last inspected shall be inspected until the extent of the unacceptable condition is determined
            - If the reason for failure is an isolated event in SEPTA's opinion, then sampling may return to the immediate previous frequency level until the severity levels are proved
            - Any change in welder, welding machines, or welding procedure specification (WPS) shall return the sampling back to 100%

5. For partial penetration welds and ring welds, comply with the following:

    a. Before production: Perform preproduction test welds from sample joints to validate the welding process and welders' trough macro-etch samples for that groove configuration. Sample joints to be used shall be proposed and **approved**.

    b. During production: Submit a CDRL including proposed test welds from critically loaded welds for periodic macro-etch samples for continued validation of the weld process and welder. Mock-up joints can be used.

        - The inspection sampling plan shall, at a minimum, meet the following:
            - 100% of the first assemblies and related subassemblies
            - 50% of the next four assemblies and related subassemblies
            - 25% of the next eight assemblies and related subassemblies
            - After severity levels have been proved, 1 welded assembly and related subassemblies out of each 10 produced

- If unacceptable welds are found, then all previous welded assemblies up to last inspected shall be inspected until the extent of the unacceptable condition is determined
- If the reason for failure is an isolated event in SEPTA's opinion, then sampling may return to the immediate previous frequency level until the severity levels are proved
- Any change in welder, welding machines, or WPS shall return the sampling back to 100%

16.6.3.6 Weld Cleaning Requirements

All welds, regardless of their location, shall be cleaned and free of flux residue, spatter, slag or other debris that may impair the function or appearance of the welded area.

Heat tint on stainless steel welds not exposed to passenger view need not be removed.

16.6.3.7 Welding Rod or Wire

Comply with the following:

1. Purchase to AWS specifications.
2. Where special materials are required that are not covered by these or other applicable AWS welding material specifications, submit the purchase specifications for **approval**.
3. Purchase welding filler materials in packages of convenient size, marked with the manufacturer's name and the specification, diameter, and net weight of the material.
4. Store the material in accordance with applicable AWS or manufacturer's recommendations, whichever is more restrictive, to protect it from damage, and so that it can be easily identified.
5. Issue and handle material in such a way as to prevent it from being mixed with that of another filler metal type and specification.

16.6.3.8 Special Welding

Comply with the following:

1. Submit procedures for structural welding of stainless steel to HSLA, or other combinations of metals or conditions not covered by AWS specifications or codes, for **approval**.
2. Use austenitic stainless steel electrodes or wire to join carbon or HSLA steels to stainless steels.
3. As part of the qualification of all dissimilar metal welds, sample welds shall be sectioned and examined metallographically to determine HAZ hardness.
    a. The HAZ or base metal hardness shall not exceed 400 HV.
    b. The hardness scan shall be done 0.5 mm (0.2 in) from the root side of the base metal. It shall start a minimum of 5 mm (0.2 in) within the base metal and proceed through the weld into

the opposite side base metal. The spacing between hardness impressions shall be 0.5 mm (0.2 in).

16.6.3.9 Resistance Welding

Comply with the following:

1. Weld stainless or carbon steels in accordance with AWS D17.2/D17.2M:
    a. Structural applications: Class B
    b. Nonstructural applications: Class C
2. Obtain **approval** for desired exceptions from AWS D17.2/D17.2M including, but not limited to weld nugget diameter, tension shear strength, and minimum spacing, before inclusion in the design or in production procedures.
3. Control current, time, electrode size, shape, and tip force to produce uniform welds of specified strength that are not subject to intergranular stress-corrosion cracking.
4. Arrange welds to avoid tension or "peeling" forces on the welds under anticipated loading condition.
5. Surface indentation:
    a. Not exposed to passenger view: Maximum 20% of material thickness (t) or 0.25 mm (0.01 in), whichever is greater
    b. Exterior areas exposed to passenger view: Maximum 10% of t or 0.13 mm (0.005 in), whichever is greater
6. Remove surface burn and discoloration by an **approved** method to match the surrounding surface.

16.6.3.10 Resistance, Spot Weld, and Intermittent Weld Spacing

Spacing of resistance and spot welds shall be appropriate to the design:

1. Spacing shall not exceed 50 mm (2 in) plus twice the weld nugget diameter for structural applications, including vehicle-body side sheets. Where weld spacing exceeds 44t on thin sheets, the maximum weld spacing may need to be reduced to prevent buckling.
2. Intermittent weld spacing shall not exceed 125 mm (5 in) for 50 mm (2 in) weld length (40% minimum). Exceptions to avoid warping in thin sheets will be considered but shall be **approved**.

16.6.4 Torch Brazing

Comply with the following requirements for brazing (above 450 degrees C (840 degrees F)):

1. Follow the recommendations in AWS Welding Handbook, Volume 2.
2. Qualify procedures and personnel in accordance with AWS B2.2/B2.2M.

3. Brazed joints shall present a workmanlike appearance in accordance with AWS C3.4M/C3.4.

4. Protect inner surfaces of air conditioning tubing from oxidizing contaminants during and after brazing operations.

16.6.5 Torch Soldering

Comply with the following requirements for soldering (below 450 degrees C (840 degrees F)):

1. Follow the recommendations in the AWS Welding Handbook, Volume 2.

2. Qualify procedures and personnel through preparation and testing of samples, as follows:

   a. Copper Piping into Fittings:

      - Each worker designated to perform this work shall prepare three copper piping connections in the vertical position.
      - The sample joints shall present a smooth, workmanlike appearance, without excess solder reinforcement.
      - Each joint shall be pressure tested using a water or air system to confirm that it is leak-free.

   b. Stainless Steel Lap Joints (Trim Seams):

      - Each worker designated to perform this work shall prepare one typical trim seam sample, using the same stainless steel materials, finish, and thicknesses as used on the actual vehicle.
      - The seam for evaluation shall be minimum 915 mm (36 in) in length and shall be set up in the horizontal position during soldering.
      - Specimen width shall be selected, or the test setup arranged, so that premature overheating of the joint does not occur.
      - Finished samples shall be saw-cut into four pieces so that eight cross-sections of the joint may be examined.
      - Exposed solder surfaces shall display a uniform, smooth contour and shall meet or exceed all applicable AWS quality standards.

16.7 Straightening

Straightening may be used to correct dimensional nonconformities only as **approved**. Submit a CDRL including personnel qualifications, straightening procedure, and testing methods, as specified in the CDRL section, below.

16.8 Elastomers

16.8.1 General

Comply with the following:

1. Material: Neoprene unless otherwise specified or **approved**.
2. Compound and cure: Suitable for the Project environment specified in Section 2, Design and Performance Criteria.
3. Quality: Free of defects of material and workmanship.
4. Performance:
    a. Highly resistant to ultraviolet, other solar radiation, and vehicle washing fluids.
    b. Resistant to ozone, oxidation, heat, oil, grease, and acid.
5. Design life of resilient parts: Minimum 10 years.

16.8.2 Applications

Comply with the following:

1. Parts made by vulcanizing an elastomer to metal:
    a. Premature failure:
        - Definition: Failure in less than five years after Final Acceptance of the vehicle.
        - Considered a defect of materials or workmanship when the failure occurs between the metal and elastomer or in the elastomer and the parts are used in normal service and according to the provisions of the Specifications.
2. Metal parts to which neoprene or other such material is cured:
    a. Material: SAE 1020 or 1045 hot-rolled steel or **approved** equal, suitable for brass plating after pickling.
3. Door mating edges, door and window seals, and glazing strips:
    a. Material: Neoprene or ethylene propylene diene (EPDM) rubber.
    b. Durometer hardness: 70 plus or minus 5 at a temperature between 20 degrees C and 30 degrees C (68 degrees F and 86 degrees F) when measured with a Shore Type "A" durometer.

16.9 Piping and Tubing (other than Air Conditioning)

16.9.1 General

Comply with the following general requirements for piping and tubing:

1. Furnish, install, and test piping, valves, and fittings in accordance with ASME B31.1.
2. Straight runs of pipe: Continuous and without fittings unless otherwise **approved**.
3. Truck piping: Shall not be run on the bottom of truck side frames, transom, or bolster.
4. Connections to resiliently mounted or moving equipment:
   a. Via hose or other resilient device, as appropriate.
   b. Clamp piping within 50 mm (2 in) of the resilient connection.
5. Piping passing through holes in fixed members:
   a. Rigidly clamp piping to support structure. Cantilevered or other flimsy piping supports are prohibited.
   b. Clamps shall not be welded, brazed, or otherwise permanently fastened to piping.
   c. Clamps shall be insulated with an **approved** elastomeric or woven mineral fabric tape to protect and acoustically insulate the piping from structure.
6. After installation:
   a. Clean piping systems by flushing with an **approved** cleaning solution
   b. Pressure test in accordance with ASME B31.1
   c. Repair leaks and retest the system until leak free

16.9.2 Hydraulic Tubing, Hose, and Fittings

Comply with the following requirements:

1. Tubing:
   a. Type: Seamless stainless steel, designed for hydraulic applications.
   b. Wall thickness: Minimum 1.65 mm (0.065 in).
   c. Bending: Tubing may be bent using a bending tool designed specifically for bending of the tubing to be used, instead of elbows.
   d. Connections: Stainless steel, flareless bite-type fittings, Parker Hannifin Ferulok®, or similar.
   e. Installation: Clean tubing sections following fabrication and cap/seal open ends. Ends shall remain sealed at all times prior to final installation.

2. Hose:

    a. Rating: Shall withstand four times the maximum operating pressure without bursting.

    b. Temperature: Hose shall not be used in locations where the temperature may exceed 100 degrees C (212 degrees F).

    c. Fittings: Permanently fitted to the hose.

    d. Openings: Cap immediately after fabrication and cleaning.

3. Joints: Keep to a minimum; inaccessible joints are not permitted.

4. Connections:

    a. To manifold ports, valve bodies, and other hydraulic system components: Use straight thread fittings with separate O-ring seals, unless otherwise **approved**.

    b. Quick connect couplings:

        - Double shutoff with valves built into both of the mating parts.
        - Shall conform to MIL-DTL-25427, or be **approved** commercial couplings providing equivalent performance.

5. Service and Isolation Devices: Provide means to safely isolate or otherwise relieve all stored energy from a portion of the system requiring service, without loss of fluid or accumulator gas (if so equipped).

16.10 Hydraulic Fluid

Comply with equipment suppliers' recommendations for performance and environmental conditions of the application, and MIL-PRF-83282, unless otherwise justified and **approved**.

16.11 Paints, Graphics, and Coatings

16.11.1 General

Comply with the following:

1. Furnish and apply paint and coatings in accordance with local, state, and federal requirements that apply at the location where paint and coatings are applied.

2. Paint, graphics, and coatings shall be repairable by SEPTA with materials and processes conforming to local, state, and federal requirements that apply to the Project.

3. Test paint performance in accordance with this Section.

16.11.2 Materials Not to be Painted

Equipment or parts of equipment that would be damaged or suffer impaired operation from painting shall not be painted, including but not limited to the following:

1. Flexible conduit and fittings
2. Copper tubing, piping, and fittings
3. Wire and cable
4. Power resistors
5. Heat transfer surfaces
6. Electrical insulators
7. Elastomeric devices
8. Grounding pads
9. Sliding pads
10. Limited slip connections
11. Bolt holes

16.11.3 Paint and Powder Coat Materials

16.11.3.1 General

Comply with the following:

1. Paint and powder coat materials shall be from a high-quality finishing system, resistant to corrosion, chipping, and fading, and shall retain the gloss level specified in Section 14.
2. Paint and filler materials that are to be superimposed to form a finish system shall be mutually compatible and shall be warranted for use as a system by the manufacturer of the components.
3. The Contractor and its liquid paint or powder coat supplier shall ensure that a continuing supply of touch-up paints in the proper colors used on the vehicle, suitable for touch-up and repair by spray, roller, or brush, will continue to be available in the United States.

16.11.3.2 Primers

Where specified, primers shall comply with the following requirements:

1. Wash (etch) primer: A primer with anti-corrosion properties for application as a first coat on metal surfaces, as recommended by the manufacturer of subsequent primer and topcoat.
2. Epoxy primer: Compatible with the polyurethane topcoat.

3. Truck primer: Compatible with truck paint.

16.11.3.3 Topcoats

Where specified, topcoats shall comply with the following requirements:

1. Polyurethane: Two-part, high solids, low VOC, polyurethane paint system; gloss or semi-gloss, as specified in Section 14.

2. Anti-skid: For surfaces requiring anti-skid coating, mix a non-skid additive into the paint, such as fine glass or plastic beads.

3. Truck paint: Select truck paint that will not hide structural cracks.

16.11.3.4 Powder Coat

Where specified or **approved** for individual applications by exception, powder coat shall comply with the following requirements:

1. Interior applications: Thermosetting, resin based, polyester or epoxy powder tailored to the individual application.

2. Exterior applications:

    a. Steel: Epoxy primer and polyester TGIC topcoat.

    b. Aluminum: Superior Performance Organic Coating in accordance with AAMA 2605.

    c. Tailored to the individual application, and suitable for long term use in exterior applications exposed to direct sunlight, temperatures specified in Section 2, Design and Performance Criteria, cleaning products, oil, solvents, and other agents to which the proposed location may be subjected.

16.11.4 Preparation and Paint or Powder Application

16.11.4.1 General

Comply with the following:

1. Prepare the substrate surface in accordance with the paint or powder manufacturer's recommendations.

2. Prepare and apply paint and powder materials according to the manufacturer's recommendations, including environmental conditions (clean, dry atmosphere at specified ambient temperature and humidity).

3. Paint materials shall be used at the consistency recommended by the paint manufacturer. If thinners are necessary, they shall be approved by the paint manufacturer and shall be used only to the extent recommended.

4. Paint and powder coating shall be uniformly applied over all surfaces to be covered and shall be free from foreign matter, runs, sags, orange peel, fisheyes, or other application defects.

16.11.4.2 Applicator Qualifications

Painting and powder coating shall be done by experienced labor, using proper equipment under competent supervision.

16.11.4.3 Vehicle Body

Comply with the following:

1. After fabricating metal portions of the vehicle body not constructed of stainless steel, prepare and prime by one of the following methods:
    a. Grit blast, then immediately after grit blasting, apply epoxy primer.
    b. Wash with an alkaline solution and properly rinse; apply a coat of phosphate or a coat of wash primer; and then coat with epoxy primer.
    c. As recommended by the manufacturer and **approved** if the manufacturer does not recommend the specified methods.
2. In addition, comply with the following requirements for the locations indicated:
    a. Enclosed surfaces capable of rusting or oxidation: After cleaning and applying epoxy primer, paint with polyurethane or other **approved** coating suitable for the vehicle design life.
    b. Arc welds between stainless steel and other materials: De-scale the joint, clean, apply wash primer, apply epoxy primer, and apply polyurethane topcoat.
    c. Concealed aluminum: Apply one coat of primer and one coat of an **approved** sealer, except to framing structures.

16.11.4.4 Exterior Not Visible to Passengers

Surfaces that are on the exterior of the vehicle but not visible to passengers shall be prepared as specified above for the vehicle body, and painted as follows:

1. Under-vehicle:
    a. Exposed portion of the underframe (except stainless steel): Apply epoxy primer and one polyurethane topcoat.
    b. Metal structures (except stainless steel), including welded brackets and appurtenances: After erecting the framing structure and body sheets, apply epoxy primer and two polyurethane topcoats.
    c. Apparatus and Equipment Enclosures (applies to interior and exterior surfaces):
        - Carbon steel: Apply epoxy primer and one polyurethane topcoat.
        - Plastic or fiberglass: Apply epoxy primer and one polyurethane topcoat. Verify that the paint system is compatible with the plastic used.
        - Paint apparatus and enclosures only after metal working activities are completed.

- Apparatus from suppliers shall be painted by the suppliers before installation on the vehicle, under the Contractor's direction and according to the Specifications and **approved** color scheme.

2. Roof: Apply epoxy primer and one polyurethane topcoat. See Section 14, Interior and Exterior Appointments, for roof surfaces on which anti-skid coating is required.

3. Other parts of the vehicle not exposed to view: Apply epoxy primer and one polyurethane topcoat.

16.11.4.5 Trucks

Paint truck frames before assembly and complete painting of truck components before installation on the vehicle:

1. Before painting, clean trucks by blowing with compressed air and wiping with solvent to remove dirt and grease.

2. After cleaning, spray truck components with one coat of primer and one coat of paint and air dry.

16.11.4.6 Exterior Visible to Passengers

Comply with the following:

1. Preparation: Before painting vehicle surface that is exposed to view, rectify dents, gashes, nicks, roughness, and other surface imperfections:

   a. Remove imperfections so far as possible by straightening.

   b. After straightening, wash prime the surface, fill remaining imperfections with an **approved** epoxy-based filler, and sand smooth.

      - Filler thickness: Maximum 3 mm (0.125 in); or
      - As recommended by the filler manufacturer for the environment and service to which it is to be exposed, whichever is less.

2. Painting: Apply epoxy primer and two polyurethane topcoats.

3. Surface appearance: The finished exterior shall present a high-quality appearance free from sags, drips, scratches, variations in gloss, and other imperfections.

   a. Comply with requirements for gloss and surface appearance in Section 14, Interior and Exterior Appointments.

   b. Test surface appearance in accordance with Section 15, Testing.

16.11.4.7 Stainless Steel and FRP

Comply with the following:

1. Painted stainless steel: Where required to be painted, the painting procedures shall be as recommended by the paint manufacturer for that application.

2. Unpainted exterior stainless steel: Clean with an **approved** alkaline cleaning solution that will not damage other painted surfaces.

3. FRP: Where required to be painted, apply one coat of epoxy primer and topcoat with polyurethane, using the number of coats recommended for the application.

16.11.5 Paint Performance Test

Comply with the following:

1. Test the final painted or powder coated surface on the first component of the production run to the following criteria:

   a. Hardness: Perform pencil hardness tests according to ASTM D3363.

      - The acceptable range is between H and 2H, based on the average of ten readings taken from typical surface locations.
      - To avoid a destructive test of a vehicle's surface that would require the tested surfaces to be repaired, the use of a test structure for this test may be proposed for consideration.

   b. Adhesion: Perform test using an Elcometer pull-off adhesion gauge.

      - Tested surfaces shall achieve a minimum rating as furnished by the paint manufacturer.
      - To avoid a destructive test of a vehicle's surface that would require the tested surfaces to be repaired, the use of a test structure for this test may be proposed for consideration.

   c. Thickness: Perform non-destructive testing to verify final dry film thickness.

      - The minimum and maximum dry film thickness shall be within the recommended criteria furnished by the paint manufacturer.
      - Dry film thickness beyond the manufacturer's recommendations will not be accepted.

   d. Paint Cure: Perform a solvent rub test per ASTM D5402.

      - The test procedure requires minimum 50 double finger rubs with a cloth wetted in acetone or methyl isobutyl ketone to the painted surface.
      - Paint color shall not transfer to the cloth.
      - After 72 hours, the painted surface shall retain all original characteristics such as gloss and hardness.

e. Surface Appearance:

- Make a visual inspection of vehicle surfaces for uniform gloss and no visible orange peel effect.
- Using a DOI (Distinctness of Image) meter, take measurements at multiple locations.
- Verify that average readings comply with specified limits in Section 14, Interior and Exterior Appointments.

2. Repeat tests during production on vehicles randomly chosen by the Engineer.
3. Test coupons shall be retained for the life of the vehicle warranty period.

16.11.6 Graphics

Comply with the following requirements for graphics, such as stripes, logos, or vehicle numbers:

1. Material: 3M vinyl graphic film or **approved** equivalent.
2. Installation: In accordance with manufacturer's recommendations using manufacturer recommended tools.

16.11.7 Other Coatings

Comply with the following:

1. Apply undercoatings and other coatings, where required, and acoustical insulating materials (see Section 14, Interior and Exterior Appointments) to cleaned and primed surfaces and members, according to the material manufacturer's recommendations.
2. These materials shall be resistant to dilute acids, alcohols, grease, gasoline, aliphatic oils, and vermin.

16.12 Flammability, Smoke Emission, and Toxicity (FST) Requirements

Test all materials provided for the vehicle to verify compliance with the flammability, smoke emission, and toxicity requirements of this section, except materials used in small parts that would not contribute significantly to fire propagation, smoke, or toxic gas generation (such as knobs, rollers, fasteners, clips, grommets, and other small parts):

1. As a minimum, materials used in the construction of the vehicle shall meet the requirements of NFPA 130 Chapter 8, Vehicles.
2. Those materials and products generally recognized to have highly toxic products of combustions shall not be used.
3. Perform tests within one year from NTP on a production batch of material intended to be used on this Contract.
4. If the quantity of a particular material is such that it would not contribute significantly to a fire, a waiver may be requested from testing for this material.

5. Material tested in accordance with NFPA 130, Chapter 8, Vehicles, shall meet the following toxic gas release limits (ppm) as determined per BSS 7239 or SMP 800C:

Carbon Monoxide (CO)	3,500 ppm
Hydrogen Fluoride (HF)	200 ppm
Nitrogen Dioxide (NO_2)	100 ppm
Hydrogen Chloride (HCl)	500 ppm
Hydrogen Cyanide (HCN)	150 ppm
Sulfur Dioxide (SO_2)	100 ppm

6. Comply with all provisions of 49 CFR 238.103 (c) and APTA PR-PS-RP-005-00.

16.13 Wood and Panels

16.13.1 Lumber

Comply with the following:

1. Lumber shall be thoroughly air seasoned or kiln dried before using and shall be dressed on all surfaces to full dimensions.
2. Lumber shall be straight grained, free from dry rot, knots, checks, and other defects that may impair its strength and durability or mar its appearance.
3. The use of wood in the vehicle, except where specified, shall be limited to specifically **approved** applications.

16.13.2 Plywood

Comply with the following:

1. Type: NIST PS 1, panel grade Structural I.
2. Storage: Store under cover.
3. Plywood panels: Formed from one piece and sealed with two coats of epoxy paint on all edges and cutouts as soon as possible after fabrication.
4. Exposed edges of panels: Treat joints between panels, fastener heads, and openings of panels used in areas accessible to moisture, before installing in the vehicle, as follows:
    a. Before sealing edges, plug splits showing on edges with wooden wedges dipped in adhesive conforming to Federal Specification MMM-A-181.
    b. Seal the exposed edges with an **approved** epoxy or polyurethane moisture barrier coating.
    c. Allow minimum 24 hours drying time between each coat.

16.13.3 Plymetal

Comply with the following:

1. Plymetal shall be metal-faced plywood conforming to the table below.
2. Plymetal faced with melamine shall have the melamine bonded to the metal sheet, and the melamine-faced metal sheet then laminated to the plywood core.

TABLE 16-2, PLYMETAL REQUIREMENTS	
Test Conditions	**Minimum Metal to Wood Average Shear Value (or 80% Wood Failure)**
Dry shear	1.7 MPa (250 lbf/in²)
Boil shear, 3 hour boil, tested wet at room temperature	1 MPa (150 lbf/in²)
Soak shear, 48 hour soak wet at room temperature	1 MPa (150 lbf/in²)
Creep or cold flow, under static load for 48 hour, at room temperature	1.7 MPa (250 lbf/in²)

16.13.4 Honeycomb Panels

Honeycomb panels shall be an assembly of honeycomb material bonded to melamine-faced metal panels or to metal panels:

1. Honeycomb Core Materials:
    a. Aluminum: Commercial grade, complying with SAE AMS C 7438.
    b. Aramid Fiber Composite: High strength, Kevlar® N636 or equivalent, para-aramid fiber paper impregnated with a heat-resistant phenolic resin, conforming to specified flammability, smoke emission, and toxicity requirements, for nonstructural applications where specifically **approved** for use.
2. Panel Skin Materials: Melamine-faced metal or metal.
3. Bonding: Sufficient to develop the full strength of the honeycomb material.

16.13.5 Melamine-Faced Aluminum

Melamine-faced aluminum panels shall be constructed by laminating melamine impregnated papers to aluminum sheets using heat and pressure. Use of adhesives for bonding is not permitted:

1. Temperature: Minimum 132 degrees C (270 degrees F)
2. Pressure: Minimum 6.9 MPa (1000 psi)

3. Minimum Thicknesses:

    a. Melamine and required binder sheets: 0.51 +/- 0.13 mm (0.020 +/- 0.005 in)

    b. Aluminum sheets, used on plywood substrate: 0.64 mm (0.025 in)

    c. Aluminum sheets, not laminated to substrate: 2 mm (0.08 in)

4. Flammability, Smoke, and Toxicity: See Flammability, Smoke Emission, and Toxicity Requirements section, above.

5. Preparation: Properly clean aluminum sheets by etching, sanding, or other **approved** process to ensure full, permanent, acceptable adhesion.

6. Quality Tests:

    a. Bond between melamine and aluminum sheets: Meet requirements of the table below.

    b. Surface characteristics, after manufacture: Comply with NEMA LD 3 type GP (General Purpose).

TABLE 16-3, MELAMINE TO ALUMINUM BOND REQUIREMENTS			
Mechanical Properties	**ASTM Method**	**Condition**	**Value**
Internal bond	ASTM D952		17.9 MPa (2,600 lbf/in²)
Flexural strength - (S)	ASTM D790	with grain	183 MPa (26,500 lbf/in²)
		cross grain	174 MPa (25,300 lbf/in²)
Modulus of elasticity - (E)	ASTM D790	with grain	19.3 GPa (2.8 x 10^6 lbf/in²)
		cross grain	21.4 GPa (3.1 x 10^6 lbf/in²)
Tensile strength	ASTM D638	with grain	154 MPa (22,300 lbf/in²)
		cross grain	140 MPa (20,300 lbf/in²)

16.13.6 Composite Floor Panels

16.13.6.1 Panels

Composite floor panels shall be a wood or foam core with the entire top and bottom surface faced with a skin consisting of fiberglass fabric impregnated with resin.

1. Core: Structurally reinforced, closed-cell, rigid foam core material or a lightweight thermoplastic foam core material.

2. Skin: Bi-axial fiberglass fabric reinforced composite material.

3. Bond: All panel components shall be permanently bonded to core by a compression molding process, co-curing the wet resin-impregnated skin directly against the core.

4. Minimum Thicknesses:

    a. Panel: 19 mm (0.75 in)

    b. Fiberglass fabric:

    - Panels supported more than 914 mm (36 in) apart: 2.5 mm (0.1 in)
    - Panels supported minimum 914 mm (36 in) apart: 1.4 mm (0.055 in)

5. Flammability, Smoke, and Toxicity: See Flammability, Smoke Emission, and Toxicity Requirements section, above.

16.13.6.2 Physical Test Requirements

Composite floor panels shall withstand the physical tests in this section with none of the following results:

1. Visible or audible indications of delamination of the panel skin from the core.
2. Puncture or damage to fibers of the top surface.
3. Separation of internal core from the top or bottom skin.
4. Fracture of core.

Composite floor panels shall comply with the following physical test requirements:

1. Static Load Test, Average Loading:

    a. Test setup: Support a representative sample section of floor panel (without floor covering) on beams spaced at the maximum spacing used on the vehicle, using production bonding and fastening techniques.

    b. Load: In accordance with crush loading requirements of Section 2, Design and Performance Criteria.

    c. Test: Apply uniformly distributed load to both sides of joint (butt or shiplap).

    d. Maximum deflection: 2.2 mm (0.088 in).

2. Static Load Test, Maximum Loading:

    a. Test setup: Same setup used for Average Loading, above.

    b. Load: 976 kg/m² (200 lb/ft²).

    c. Test: Apply uniformly distributed load to both sides of joint (butt or shiplap).

3. Small Area Static Load Test:

    a. Test setup: Same setup used for Average Loading, above.

    b. Load: 136 kg (300 lb)

c. Contact device: Footprint 25 mm by 75 mm (1.0 in by 3.0 in), machined flat within 0.25 mm (0.010 in) and edges radiused maximum 3.2 mm (0.125 in).

d. Test: Apply load to the contact device located directly over midspan, 150 mm (6 in) from outer vehicle-body sidewall edge.

e. Maximum deflection: 5 mm (0.20 in).

4. Indentation Resistance:

a. Test setup: Representative sample section of floor panel laid on a level surface.

b. Load: Test dowel with the following characteristics:

- Overall surface area: 242 sq mm^2 (0.375-sq in^2)
- Radius on bottom edge: 1.6 mm (0.0625-in)

c. Test: Apply a concentrated load of 136 kg (300 lbs) to test dowel.

d. Maximum permanent deformation of top surface: 0.25 mm (0.010 in).

5. Small Object Impact Test:

a. Test setup: Same setup used for Average Loading, above.

b. Load: 7.26 kg (16 lb) standard bowling ball.

c. Test: Drop load from height of 1500 mm (60 in) directly over mid-span, 610 mm (24 in) from edge of panel.

d. Maximum permanent deformation of top surface: 1.587 mm (0.0625 in).

6. Large Object Impact Test:

a. Test setup: Same setup used for Average Loading, above.

b. Load: 68 kg (150 lb)

c. Contact device: Footprint 75 mm by 200 mm (3.0 in by 8.0 in), with rubber pad on the downside surface having the following characteristics:

- Minimum Shore D 70
- Thickness: 25.4 mm (1 in)
- Machined flat within 1.524 mm (0.060 in) with edges having a radius of not more than 0.8 mm (0.030 in)

d. Test: Drop load from height of 300 mm (12 in) onto contact device located directly over midspan, 610 mm (24 in) from edge of panel.

e. Maximum permanent deformation of top surface: 0.8 mm (0.030 in). Some damage to top phenolic composite skin will be allowed.

7. Rolling Load Test:

   a. Test setup: Same setup used for Average Loading, above.

   b. Load: Four-wheeled cart with load of 91 kg (200 lb) per wheel. Wheels shall have the following characteristics:

      - Diameter: 75 mm (3 in)
      - Width: 25 mm (1 in)
      - Radius: 3 mm (0.125-in) on each edge
      - Material: Shore A durometer of 80

   c. Test: Roll load onto panels laterally, longitudinally, and in a circular path with radius 610 mm (24 in).

   d. Maximum permanent deformation of top surface: 0.25 mm (0.010 in).

16.13.7 Flatness

Comply with the following:

1. Surfaces exposed to passengers may exceed the specified contour by maximum 2.5 mm (0.1 in) in any 1 m (39 in) distance.

2. The slope of any such irregularity shall be maximum 2 mm (0.08 in) in 100 mm (4 in).

16.14 Fiberglass Reinforced Plastic (FRP)

16.14.1 General

Comply with the following:

1. Material: Polymeric-reinforced, laminated material, composed of a gel-coated surface, fiberglass reinforcement, and a polyester, vinyl ester or other **approved** resin.

2. Chemical resistance: FRP shall be resistant to acids, mild alkaline solutions, and those cleaning solutions recommended by the Contractor.

3. Environmental resistance: FRP shall withstand, without any physical deformation, structural damage, or reduction in life, the environmental conditions in Section 2, Design and Performance Criteria.

16.14.2 Composition

Comply with the following:

1. Additives, fillers, monomers, catalysts, activators, pigments, fire retardants, and smoke inhibitors shall be added to the resin mixes to obtain finished products with the required physical characteristics below and other requirements of this document.

2. Mineral filler shall not exceed 28% of finished weight for any preformed matched die molding process.

16.14.3 Gel Coat

Comply with the following:

1. The gel coat shall be weatherproof, match the **approved** color and gloss as specified and **approved** in Section 14, Interior and Exterior Appointments, and contain UV inhibitors to protect the FRP from ultraviolet radiation for a minimum of 30 years.
2. If a low gloss finish is required, paint the FRP in accordance with this Section.

16.14.4 Manufacturing

Comply with the following:

1. Qualifications: FRP suppliers shall be experienced with manufacturing FRP structures of similar sizes and complexities, with materials and standards as defined in this Section.
2. Manufacturing Techniques:
   a. FRP shall be manufactured by hand-laminated open molding, or as appropriate for the part and **approved**.
   b. Production techniques shall ensure that the glass fiber reinforcement is uniformly distributed throughout the final product in such a manner as to avoid resin-rich or resin-starved sections.
3. FRP parts:
   a. Thickness: Minimum 3 mm (0.120 in)
   b. Thickness at attachment points and edges: Greater than minimum thickness.
   c. Exposed sharp edges: Not permitted on any parts.
4. Quality:
   a. Inspect FRP materials at the point of manufacture for voids, density variations, and other internal defects, thickness variations, finish, and other defects.
   b. Except for minor surface defects, repairs to FRP are not permitted.
   c. Defective material shall be discarded.

16.14.5 Strength Requirements

16.14.5.1 General

Perform independent laboratory tests in accordance with Section 15, Testing, to confirm that products comply with the strength requirements below.

16.14.5.2 Nonstructural (No load)

Minimum strength requirements are defined below for items that are nonstructural or will not be exposed to any loads, such as window masks, destination sign shrouds, ceiling cove panels, and ceiling headers:

TABLE 16-4, FRP NONSTRUCTURAL (NO LOAD) STRENGTH REQUIREMENTS		
Mechanical Property	**ASTM Test**	**Required Value**
Tensile Strength	D638	69 MPa (10,000 lbf/in^2)
Compressive Strength	D695	124 MPa (18,000 lbf/in^2)
Flexural Strength	D790	103 MPa (15,000 lbf/in^2)
Impact Strength	D256	5.3 J/cm (10 ft-lb/in) of notch
Hardness	D2583	45 Barcol

16.14.5.3 Structural (Load)

Minimum strength requirements are defined in the table below for items that are structural or will be exposed to loads from passengers or impacts, such as end bonnets, side skin, under floor equipment enclosures, door pocket panels, wainscot panels, passenger seat back shrouds, and windscreens:

TABLE 16-5, FRP STRUCTURAL (LOAD) STRENGTH REQUIREMENTS		
Mechanical Property	**ASTM Test**	**Required Value**
Tensile Strength	D638	124 MPa (18,000 lbf/in^2)
Compressive Strength	D695	165 MPa (24,000 lbf/in^2)
Flexural Strength	D790	206 MPa (30,000 lbf/in^2)
Impact Strength	D256	6.9 J/cm (13 ft-lb/in) of notch
Hardness	D2583	45 Barcol

16.14.6 Fiberglass Reinforced Plastic (FRP) Performance Test

Test FRP coupons trimmed from production parts:

1. Perform a visual examination for porosity, voids, and other imperfections visible in the cross section.

2. Verify compliance with the strength requirements specified in Section 16, Materials and Workmanship. Tests shall be performed by an independent laboratory. Condition test specimens in accordance with ASTM D618.

16.14.7 Bonding

Seams and joints from FRP to FRP/metals shall be fully bonded to prevent moisture ingress and provide corrosion protection. Adhesives shall be two-part epoxy adhesives to be submitted for **approval**.

16.14.8 Shipping and Handling

Perform special handling for any large, complex FRP parts such as the front end, including enclosing parts in custom frames or crates. Conduct a detailed receiving inspection for each such part.

16.14.9 Installation of FRP Front End

Comply with the following installation requirements for FRP vehicle front end:

1. Where FRP is used for the vehicle front end, excessive force shall not be used during assembly onto the vehicle structure.

2. Minor trimming to fit will be permitted only at the discretion of SEPTA.

3. After assembly of the front end onto the vehicle, notify SEPTA of any cracks, voids, or defects.

    a. The defective front end shall be removed and replaced unless SEPTA **approves** a repair.

    b. The determination to remove and replace or repair the defective part shall be solely at the discretion of SEPTA with no additional costs to be borne by SEPTA.

16.15 Thermoplastic Sheet

16.15.1 General

Thermoplastic sheet shall:

1. Withstand the environmental conditions in Section 2 without physical deformation or structural damage.

2. Be resistant to all recommended cleaning agents.

3. Meet the relevant requirements in the Flammability, Smoke Emission, and Toxicity section, above.

Thermoplastic sheet shall be used as extruded or pressure-formed, or as **approved**.

16.15.2 Product Requirements

Thermoplastic sheet: Through-colored, homogeneous and extruded from virgin stock, which shall not include any regrind of vacuum formed parts.

Thermoplastic in final form:

1. Surface finish gloss: Level shall not vary by more than 5 points, as measured using a 60° glossometer.

2. Surface texture: Shall not fade out at or near part contours.

3. Color, texture, and gloss: Exposed surface shall conform to Section 14, Interior and Exterior Appointments. Only UV stabilized pigments shall be used to create the specified color.

4. Anti-graffiti coating: Provide on exposed surfaces.

5. Quality: Free of waves and quilting on both sides.

6. Defects: Following is cause for rejection of the piece:

   a. Degraded polymer.

   b. Voids, lumps, and contamination if the defects are larger than 0.25 mm (0.010 in) and the population is greater than one defect in 0.37 m² (4 ft²).

16.15.3 Strength Requirements

Thermoplastic sheet shall comply with the requirements of the standards listed in the table below. Use extruded sheet in the specified surface finish for testing.

TABLE 16-6, THERMOPLASTIC SHEET STRENGTH REQUIREMENTS		
Mechanical Properties	**ASTM Method**	**Value**
Specific Gravity	D792	1.20 to 1.45
Tensile Strength	D638	48 N/mm² (7,000 lbf/in²) minimum
Flexural Strength	D790	69 N/mm² (10,000 lbf/in²) minimum
Flexural Modulus	D790	3100 N/mm² (4.5 x 10^5 lbf/in²)
Hardness Rockwell	D785	90 to 120 "R" Scale
Heat Shrinkage		10% maximum 15 minutes at 177 degrees C (350 degrees F)
Heat Deflection (annealed)	D648	88 degrees C (190 degrees F) minimum @ 182 N/cm² (264 lbf/in²)
Impact Strength	D5420	
Gardener Dart Drop, 13 mm (0.5 in) diameter ball:		
@ 23 degrees C (73 degrees F)		369 kg-cm (320 in-lb) minimum
@ -29 degrees C (-20 degrees F)		92 kg-cm (80 in-lb) minimum

16.16 Raceways and Junction Boxes

16.16.1 Scope

This section applies as follows:

1. Raceways include conduit and wireway, both nonmetallic and metallic.
2. Junction boxes are boxes that are part of the raceway system, and include both pull boxes and boxes for electrical connections.
3. Equipment enclosures and electrical lockers are specified in Section 14, Interior and Exterior Appointments.

16.16.2 General Requirements

Comply with the following:

1. Locate raceways and junction boxes to avoid mechanical damage.
2. If the installation of raceways or junction boxes causes the connection of dissimilar materials, the installation shall comply with the requirements for dissimilar materials in this Section.

16.16.3 Conduit

16.16.3.1 Permitted Conduit Types

Comply with the following:

1. Flexible Nonmetallic Conduit:
   a. Use: May be used where flexibility is required but not where subject to physical damage.
   b. Conduit: Material meeting the flammability, smoke emission, and toxicity requirements of this Section.
      - Interior use: Rated IP64 with fittings
      - Exterior use: UV resistant and rated IP66 with fittings
   c. Terminations: Manufactured by the conduit manufacturer for the conduit selected and suitable for the application.
   d. Fittings to secure conduit:
      - For corrugated-exterior-wall type: Clips manufactured for the purpose by the conduit manufacturer and designed to restrain longitudinal motion.
      - For smooth-exterior-wall type: Two-hole, heavy-duty galvanized steel straps, manufactured for the size of conduit they are used to secure.

2. Liquidtight Flexible Metal Conduit:

    a. Use: May be used in the same locations as flexible nonmetallic conduit, except where exposed to accidental impact damage, such as under the vehicle ends.

    b. Core: Flexible galvanized steel with a continuous copper bonding conductor spiral wound between the convolutions.

    c. Jacket: Extruded liquid-tight plastic or neoprene meeting the flammability, smoke emission, and toxicity requirements of this Section; moisture- and oil-proof. If used in exterior locations, jacket shall be UV resistant and rated IP66 with fittings.

    d. Terminations: Zinc-coated steel.

    e. Fittings to secure conduit: Two-hole, heavy-duty galvanized steel straps, manufactured for the size of conduit they are used to secure.

3. Rigid Metal Conduit:

    a. Use: May be used where flexibility is not required.

    b. Conduit, elbows, nipples: Steel, hot-dip galvanized inside and out after threading, UL listed, complying with ANSI C80.1.

    c. Couplings and Terminations: Steel, galvanized, threaded type.

    d. Bushings: Nylon insulated, metallic.

    e. Fittings to secure conduit: Two-hole, heavy-duty galvanized steel straps, manufactured for the size of conduit they are used to secure.

16.16.3.2 Conduit Color Coding

Color code conduits as follows:

1. Red for those carrying circuits above 100 V.

2. Yellow for those carrying circuits below 100 V.

16.16.3.3 Conduit Fill

Conduit fill shall not exceed the maximum fill permitted by NFPA 70, Chapter 9, Tables, Table 1, Percent of Cross Section of Conduit and Tubing for Conductors and Cables, including allocation of space for future wires.

16.16.3.4 Conduit Installation

Comply with the following:

1. General:

    a. Install conduit to prevent moisture traps and arrange to gravity-drain toward control boxes or an open end.

   b. Install conduit such that wire and cable may be installed after conduit installation without using power equipment and without exceeding the allowed wire or cable pulling tension or sidewall tension.

   c. For communications cabling, install conduit with no more than 180 degrees total bend between junction boxes as per TIA-569.

2. Flexible Nonmetallic Conduit: Install conduit in accordance with the requirements of NFPA 70, Article 356, Liquidtight Flexible Nonmetallic Conduit, including but not limited to the number of bends in one run, bend radii, and securing and supporting conduit.

3. Liquidtight Flexible Metal Conduit: Install conduit in accordance with the requirements of NFPA 70, Article 350, Liquidtight Flexible Metal Conduit, including but not limited to the number of bends in one run, bend radii, and securing and supporting conduit.

4. Rigid Metal Conduit:

   a. Install conduit in accordance with NFPA 70, Article 344, Rigid Metal Conduit, including but not limited to how bends are made, the number of bends in one run, bend radii, reaming and threading, securing and supporting conduit, and use of bushings.

   b. After threading, clean to remove threading oil and protect from corrosion with minimum two coats of brushed on cold galvanizing compound.

   c. If conduit is terminated at floor level, extend minimum 25 mm (1 in) about the floor to prevent entrance of liquid.

   d. Clean conduit after installation by pulling through a brush or swab.

16.16.3.5 Conduit Connections to Boxes and Enclosures

Comply with the following requirements:

1. Configure conduit connections to boxes and enclosures as follows:

   a. So that structural, electrical, and environmental integrity is maintained.

   b. To facilitate removal and replacement of the equipment enclosure. Conduit entries into removable equipment boxes shall be secured by means of a bolt-on watertight access panel.

2. Connect conduit to underfloor and roof equipment enclosures using watertight connectors. The entrance of conduit into the top and bottom of equipment boxes is prohibited.

16.16.4 Wireway

16.16.4.1 Scope

Wireway includes wire duct, trough, channel, or other means, not including conduit, used to contain electrical wire, electrical cable, or communications cable.

16.16.4.2 General Requirements

Comply with the following:

1. Use restrictions: Use only where it will remain permanently accessible, such as where installed in electrical lockers or behind removable panels.
2. Design and installation: Ensure that wire and cable can be installed without damage:
    a. Surfaces and edges: Designed to prevent damage to wire and cable insulation.
    b. Wire entry and exit points: Provide additional wire protection and support.
3. Wire management:
    a. Provide means to securely fasten wire and cable within wireways to prevent movement and chafing, but allow changes to be made throughout the lifetime of the vehicle.
    b. Wires shall be secured such that ties or straps do not pinch or damage cable. Uncalibrated cable ties are prohibited.
4. Barriers: If used for conductors of different voltages, provide circuit separation as specified in the Circuit Separation section, below.

16.16.4.3 Interior

Interior wireway may be nonmetallic or metallic, as appropriate for the application:

1. Nonmetallic wireway:
    a. Material shall be low-smoke, halogen-free, complying with requirements for flammability, smoke emission, and toxicity in this Section.
    b. Wireway shall be designed for the intended purpose and may be solid or slotted.
    c. Provide a removable cover.
    d. Attach securely to the vehicle structure using specified fasteners; adhesive fasteners are not permitted. Secure at intervals complying with NFPA 70, Article 378, Nonmetallic Wireways.
2. Metallic wireway: Meet the requirements for exterior metal wireway.

16.16.4.4 Exterior

Exterior wireway shall be metallic, unless otherwise **approved**, and shall comply with the following:

1. Material: Stainless steel.
2. Drains: Provide to prevent accumulation of water, unless made with perforated material.
3. Covers: Removable.
4. Installation: Attach securely to the vehicle structure using specified fasteners. Secure at intervals complying with NFPA 70, Article 376, Metal Wireways.

16.16.5 Junction Boxes

16.16.5.1 General

Comply with the following general requirements for interior and exterior junction boxes:

1. Manufacturer: The Contractor or a regular manufacturer of electrical junction boxes.
2. Interior finish: Primed and painted white.
3. Covers: Gasketed and retained by spring-type latches or captive screws as **approved** on a location-by-location basis. Fasteners shall be stainless steel.
4. Orientation: Junction boxes shall be orientated so as to be directly accessible for maintenance.

16.16.5.2 Exterior Junction Boxes

Exterior junction boxes shall meet the general requirements for junction boxes. In addition, they shall be stainless steel.

16.16.6 Bonding and Grounding Metallic Raceway and Junction Boxes

Metallic raceway and junction box installations shall comply with the following:

1. Provide appropriate fittings such that raceways and connected junction boxes are mechanically and electrically continuous.
2. Provide additional bonding jumpers or internal grounding wires if necessary for electrical continuity.
3. Safety ground raceway and junction boxes to the vehicle structure in accordance with Section 9, Electrical Equipment.

16.17 Wire and Cable

16.17.1 General

Comply with the following general requirements for all wire and cable used on the vehicle:

1. Comply with EN 50343 or NFPA 70.
2. Limit the number of wire types and sizes to the extent possible.
3. Comply with the flammability, smoke emission, and toxicity requirements of this Section and NFPA 130.
4. Provide wire and cable suitable for the application.

16.17.2 Wire and Cable Type Requirements

16.17.2.1 Conductors

Comply with the following:

1. Material: Soft (annealed) copper.
2. Plating: As indicated in standards referenced for wire types in the Insulation section, below, or if not indicated, in accordance with temperatures below:
    a. 150 degrees C or less: Tinned; ASTM B33.
    b. 250 degrees C or less: Silver-plated; ASTM B298.
    c. 450 degrees C or less: Nickel-plated; ASTM B355.
3. Stranding: Suitable for the application. Provide extra-fine wire stranding for applications subject to repetitive motion, where superior flexibility is necessary for proper installation, or as specified elsewhere in the Contract Documents.

16.17.2.2 Insulation

Comply with the following:

1. Flexibility: For wire sizes No. 6 AWG and larger, the insulation material shall be formulated for extra flexibility.
2. Voltage Rating:
    a. Nominal voltages 300 V or less: Insulation shall be rated 600 V, ac and dc.
    b. Nominal voltages greater than 300 V: Insulation shall be rated 2000 V, ac and dc.
3. General Vehicle-Body Wiring:
    a. Sizes No. 12 to No. 28 AWG: Teflon®, mineral-filled, abrasion-resistant insulation; or
    b. All sizes: Flame retardant, flexible, cross-linked polyolefin complying with ICEA S-95-658, having a continuous temperature rating of 110 degrees C (230 degrees F) or 125 degrees C (257 degrees F), as appropriate for the application.
    c. Flammability, Smoke Emission, and Toxicity Standards:
        - NFPA 130
        - 49 CFR 238
        - ASTM E662 in flaming and non-flaming modes
        - BSS 7239 or Bombardier SMP 800C
        - IEEE 1202
        - UL 1685

4. High Temperature Applications (in excess of 125 degrees C or as needed for application):

   a. Sizes No. 16 AWG and Larger:

      - Abrasion resistant and cut-resistant jacket meeting all general vehicle-body wiring requirements above, while meeting temperature to be expected in operation

   b. Sizes No. 18 AWG and Smaller:

      - Abrasion resistant and cut-resistant jacket meeting all general vehicle-body wiring requirements above, while meeting temperature to be expected in operation

   c. Wire used in high-temperature applications for interconnecting shall be in bundles with a high-temperature rated, low-smoke generating, insulated protective covering.

5. In Equipment: Wiring within replacement modular units, electronic apparatus such as cards and card racks, and other equipment, as **approved**, shall be one of the following:

   a. Cross-linked polyolefin insulated wire, as described for general vehicle-body wiring, above.

6. Crowded Locations (Cab Console or similar locations):

   a. When used for this application, bundle these type wires with a protective covering of cross-linked modified polyolefin or similar high-temperature rated, low-smoke generating insulation.

16.17.2.3 Multiconductor Cables

Where multiconductor cable is **approved**, comply with the following:

1. Conductors and insulation: As described above.

2. Fillers: Where required to obtain a circular cross-section, fillers shall be made of non-hygroscopic materials compatible with the wire insulation and jacket, and shall be of the same or of a higher temperature rating than the wire insulation.

3. Binder Tape: Non-hygroscopic, of the same (or better) temperature class as the wire insulation, and of a compatible material. Apply if needed to assist in cable manufacture, or as required to permit the cable to function as intended in its application.

4. Shield (if required): Either tin-plated copper braid, concentrically-served copper, or aluminum/polyester tape with a drain wire, as appropriate for the application. Tape shields shall be permitted for fixed installations only.

5. Overall jacket: Same as general vehicle body wiring above.

6. Identification:

   a. Individual conductors in multi-conductor cables shall be color coded or otherwise permanently identified as **approved**.

b. Overall jacket shall be permanently marked at maximum 1 m (3 ft) intervals with the following information, as a minimum:

- Conductor size
- Number of conductors
- Voltage rating
- Jacket type
- Date of manufacture (Month/Year)

16.17.2.4 Ethernet Cable

For network cabling, provide industrial-grade Ethernet cable designed for reliable performance in a transit environment:

1. Conductors: Tinned copper, solid or stranded as required for the application and specified performance.
2. Shielding: Provide if required to obtain specified performance.
3. Jacket: Abrasion-, moisture-, and UV-resistant.
4. Construction:
   a. Suitable for the intended installation method.
   b. In compliance with flammability, smoke emission, and toxicity requirements of this Section.
   c. Minimum IP66 rated in accordance with IEC 60529 when mated with specified connectors.
5. Identification: Cable shall be permanently marked at maximum 1 m (3 ft) intervals with the following information, as a minimum:
   a. Electrical performance rating (e.g. Cat 5e)
   b. Number of pairs and size (AWG)
   c. Date of manufacture (Month/Year)

16.17.3 Wire and Cable Application and Installation Requirements

16.17.3.1 General

Comply with the following:

1. Wire and cable shall be applied and installed as indicated in NFPA 70, Chapter 3, Wiring Methods and Materials, APTA PR-E-RP-002-98, NFPA 130, and IEEE Std 16, except where otherwise specified in the Contract Documents, in which case that wire shall be as specified.
2. Vehicle wiring shall have circuit protection conforming to NFPA 70, Article 240, Overcurrent Protection.

16.17.3.2 Wire Sizes

Comply with the following:

1. Size wiring for the intended load, voltage drop, application, and installation method.

2. Wire and cable ampacity shall comply with NFPA 70, Section 310.15, Ampacities for Conductors Rated 0-2000 Volts. Where the temperature rating of the **approved** wire or cable is not included in Section 310.15 tables, manufacturer's ratings may be used, if the rating method is consistent with NFPA 70, Section 310.15.

3. Regardless of load, minimum wire sizes shall be as follows:

    a. Wire pulled through conduit: No. 14 AWG

    b. Wire on electronic units, cards, and card racks: No. 28 AWG

    c. Wire laid in, rather than pulled through, wire ducts: No. 16 AWG

4. Wires sizes other than the above shall be only as **approved**.

16.17.3.3 Insulation Level

Wiring within enclosures shall be insulated for the highest voltage in the enclosure, unless **approved** otherwise.

16.17.3.4 High-Temperature Wire

Comply with the following:

1. If used for interconnecting pieces of apparatus, high-temperature wire shall be in bundles with a high-temperature rated protective covering.

2. High-temperature insulated wire shall not be used in conduit or raceways without specific **approval**.

16.17.3.5 Circuit Separation

Comply with the following:

1. Circuits shall be physically separated to reduce the possibility of unsafe conditions, interference, or equipment damage.

2. The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit, and shall be physically separated and secured in enclosures, wire ducts, junction boxes, or other wire routing devices:

    a. High-voltage circuits

    b. AC circuits

    c. Communication circuits (except PA speakers and microphones, radio antennas)

   d. CBTC Circuits

   e. Primary PA system circuits

   f. Secondary PA system circuits

   g. Radio antenna circuits (separate per antenna)

   h. Battery voltage level circuits

   i. Semiconductor voltage level circuits

3. Wiring operating at potentials differing by 50 V or more shall be separated as follows:

   a. Shall not be harnessed or cabled together

   b. Shall not be run in conduit together

   c. In wireway, junction boxes, or other wire routing devices shall be separated by a rigid physical barrier

   d. Within equipment enclosures shall be separated, routed, and secured such that contact between wiring is not possible

4. Provide separation or electromagnetic shielding or both between the conductors of high-current switching or transient-generating equipment and the wiring of semiconductor, logic, or communication circuits such that interference does not occur between circuits.

16.17.3.6 Spare Wires

Comply with the following:

1. Provide a minimum of 10% spare wires in each harness or group of wires between equipment enclosures, but no fewer than two spares for each wire size.

2. Unless specifically **approved**, spare wiring shall not be used by the Contractor.

3. Install spares in connectors on terminal boards or other **approved** means.

4. Spare wires shall have enough length to reach any location within the box, including sufficient slack for the required number of reterminations.

5. The ends of the spare wires shall be insulated against inadvertent contact with any nearby conductive surfaces or terminals.

16.17.3.7 Wire Handling

Comply with the following:

1. Wiring shall be installed by qualified and experienced wiring personnel:

   a. Use appropriate tools for work such as stripping insulation, cutting, tinning, soldering, harness making, and attaching terminals.

   b. Use wiring tools and equipment as recommended by the tool and equipment manufacturer.

2. Wire shall be protected from damage during all phases of equipment manufacture.

   a. Wire shall not be walked on, dragged across sharp or abrasive objects, kinked or twisted, or otherwise mishandled.

   b. The ends of wire shall not be permitted to lay on wet floors or other damp areas where moisture may be absorbed into the conductors.

3. When removing insulation, wire strands shall not be nicked or broken.

16.17.3.8 Wiring Location Requirements

Comply with the following restrictions on location:

1. Locate wiring such that heat sources, maintenance access, and the Project environment do not damage or reduce the life of the wiring.

2. Wiring shall not pass through or over the battery compartment, or over heat-generating equipment such as acceleration and braking resistors.

16.17.3.9 Wiring Methods

Comply with the following requirements for wiring methods:

1. Wiring Type Requirements:

   a. Exposed wiring: Keep to a minimum; subject to **approval**.

   b. Multi-conductor cabling:

      - Keep to a minimum; subject to **approval**.
      - Shall not be exposed with the following exceptions:
        - Coupler cables with additional jacketing or armor
        - Wiring to standard small devices, such as speed sensors, that cannot accept conduit fittings

   c. Under-vehicle and roof wiring: Waterproof, including entrance and exit points from equipment enclosures or wiring devices.

2. Raceway Requirements:

   a. Wire smaller than No. 6 AWG shall be installed in conduit or wireway unless it is an integral part of equipment or is contained within an enclosure.

   b. Wiring to resiliently mounted or moving equipment shall be by flexible conduit.

   c. Wire No. 6 AWG or larger may be cleated in place without conduit or wireway.

3. Securing:

   a. Wiring shall be secured and protected against movement, chafing, and contact with conductive, sharp, or abrasive objects and surfaces such that normal equipment motion does not damage or reduce the life of the wiring.

   b. Wiring shall not be secured directly to the vehicle structure, equipment enclosures, or any metallic surface.

   c. Wire ties: May be used only to secure or bundle wire and cable within wireway, where exiting wireway or entering equipment enclosures, and within equipment enclosures. Wire ties shall be calibrated to not pinch cables.

16.17.3.10 Wire and Cable Installation in Conduit

Install wire and cable in conduit without using power equipment and without exceeding the manufacturer's allowed wire or cable pulling tension or sidewall tension:

1. Clean the conduit just before installation of wire or cable by pulling a brush or swab through.

2. Simultaneously install all cables to be placed in one duct.

3. Use extreme care in installing wire and cables so as to avoid twisting, kinking, scraping, or injuring outer sheath.

4. Use continuous lengths of wire and cable between power source and equipment. Splices are prohibited.

5. Wiring within conduit shall not be bundled or secured.

6. Pulling compound, if used, shall be nonconductive, non-hygroscopic, non-odorous and shall not attract vermin.

16.17.3.11 Wire and Cable Installation in Wireway

The installation of wire and cable in wireway shall comply with the requirements of NFPA 70 Article 376, Metal Wireways, or Article 378, Nonmetallic Wireways, including but not limited to the size of conductors, number of conductors, and ampacity of conductors based on wireway fill.

Comply with the following:

1. Wire and cable shall be laid into wireway. If pulling is required, prepare a pulling plan documenting the wire or cable manufacturer's minimum acceptable bend radius and maximum tension during pulling.

2. To the extent possible, install all wire and cable in a wireway at the same time, unless physical separation barriers are provided.

3. Wire and cable shall be installed neatly and fastened securely to eliminate movement and chafing.

4. When wire and cable is in its final position, inspect to ensure that it has sufficient bend radius, and that there is no sagging, pinching, or possibility of chafing that could cause damage over time.

16.17.3.12 Wire and Cable Installation by Cleating

Comply with the following:

1. Cleat Type:
    a. Split-block cleats of fire-retardant neoprene rubber with a durometer of 50 to 60.
    b. Neoprene blocks shall be clamped together with minimum two bolts with a rigid stiffener on each side of the cleat.
    c. Stiffeners shall ensure that clamping pressure is evenly distributed over the full length of the cleat.
2. Cleat opening:
    a. Molded into the material by an experienced manufacturer.
    b. Sized only for the intended wire size such that it firmly grips the wire without insulation damage or cold flow. Shimming of oversized openings is not permitted.
    c. Cutting, drilling, or modification of cleat openings during vehicle construction is prohibited.
3. Installation:
    a. Route and support wiring such that each individual run of wiring cannot contact other wiring or any other part of the vehicle under any circumstances.
    b. Cleat spacing: Maximum 0.5 m (18 in).
    c. Drip loop: Provide on exposed wiring to prevent fluid runoff into connected equipment.

16.17.3.13 Wiring Within Enclosures

Wiring within enclosures shall be attached to wire supports rigidly fastened to the enclosure structure. Comply with the following requirements:

1. Wiring shall be clear from edges, bolt heads, and similar areas, and shall not interfere with or contact enclosure covers.
2. Wiring shall be located on the top or sides of the enclosure. Wiring shall be a minimum of 25 mm (1 in) above the bottom of the enclosure, including wiring that must connect to the bottom of apparatus.
3. Wiring entering a removable enclosure shall be harnessed and secured to facilitate removal of the enclosure. Wires entering an enclosure from different raceways shall not be harnessed together or with internal wiring.

4. Wiring shall be secured such that there is no strain on wire terminals, multi-pin connector pins, or other wire termination hardware.

5. Wire dress shall allow for sufficient slack at terminals to allow for shock and vibration induced movements, equipment shifting, alignment, cover removal, and component replacement.

6. Provide additional wire length for retermination of wires without excess tension or splicing as follows:

    a. No. 10 AWG and smaller: Four reterminations

    b. No. 8 AWG and larger: Three reterminations

16.17.3.14 Identification

Comply with the following:

1. Devise a wire and terminal designation system that will coordinate each electrical circuit in the vehicle into a unified system:

    a. The system shall identify wiring, including circuit return wiring, and terminals according to their respective circuit function(s), and shall accurately correlate with the Integrated Schematic Diagrams.

    b. Common designations for return circuits are not permitted.

    c. Alternative designations may be used with **approval** in small standard assemblies, such as PA amplifiers.

2. Clearly identify each terminal and identify each wire with both its circuit designation, and, if attached to a terminal, its terminal designation.

    a. Mark wires within 75 mm (3 in) of the end of the wire.

    b. Provide heat-shrink machine-printed sleeve labels that fit snugly around wire or cable after heat is applied, or continuous wire marking printed on the wire.

        - Material: Heat shrinkable, fire retardant, zero halogen, oil and grease resistant, suitable for the worst-case combinations of ambient and equipment temperatures.
        - Printing: Chemical and abrasion resistant.
        - Color: White or yellow with black printing.

    c. Color coded wires are permitted as an alternative in small standard assemblies such as PA amplifiers.

16.17.3.15 Wire Ties, Clamps, and Anchors

Comply with the following:

1. Wire ties shall be nylon formulated for resistance to ozone and ultraviolet light, rated for outdoor service.

2. Wire ties:

   a. Select width for intended wiring load and minimum insulation indentation.

   b. Install with tools with automatic tensioning devices, as supplied by the wire tie manufacturer.

   c. Install with sufficient tension to restrain the wiring but without indenting the wire insulation.

   d. Install with cut ends flush with the locking mechanism.

3. Wire clamps:

   a. Wire clamps shall be either nylon as specified above for wire ties or stainless steel covered with neoprene or silicon rubber, such as Adel clamps as manufactured by Adel Wiggins.

   b. Size for each harness such that minimum 90% of the harness circumference is securely clamped.

   c. Fasten clamps with bolts and elastic stop nuts.

4. Wire tie anchors (if used):

   a. Material: Nylon, as specified above for wire ties.

   b. Installation: Fasten to a rigid structure using rivets or screws; adhesive-based wire tie anchors are prohibited.

16.18 Wire Terminations

16.18.1 General

Wiring shall terminate in **approved** connectors or on terminal boards:

1. Provide junction boxes or equipment enclosures for all wire terminations or circuit branches.

2. Stranded wiring used for spring clamp or screw clamp connections shall be ferruled.

3. Wire splicing is prohibited.

4. Inline connectors and splice packs are prohibited.

5. Solder connections are prohibited.

6. Butt splices are prohibited.

16.18.2 Terminal Boards

Definition of Terminal Board: Device commonly called terminal block, terminal strip, terminal stud, or similar, to which wires are connected.

Comply with the following requirements for terminal boards:

1. Shall be of a series service proven in rail transit.
2. Conducting portion: Plated copper.
3. Insulating portion:
   a. Strong, high temperature rated, tracking resistant material that is not brittle.
   b. The material shall be either a filled reinforced thermosetting material or a thermoplastic material.
   c. Use of general purpose phenolic is prohibited.
4. Clamps, screws, or other hardware: May be plated steel.
5. Jumpers between adjacent terminals: Plated brass or copper.
6. Spare terminal requirements:
   a. Less than 100 terminals: Minimum 10% spare, but no fewer than one unused terminals.
   b. 100 terminals or more: Minimum 10 spare, plus 2 for every 50 additional terminals above 100.
7. Number of wires permitted:
   a. Screw compression-clamp terminal boards: Connect a maximum of two terminals to each binding terminal.
   b. Other terminations: Only one wire per terminal is permitted.
8. Provide adequate space to permit connecting wire terminals with standard tools.

16.18.3 Non-Power Wiring Terminations

Comply with the following:

1. Terminate wires as appropriate for the intended terminal block, as recommended by the terminal block or device manufacturer.
2. Where bare wire terminations are not recommended by the manufacturer or are prohibited, provide terminations complying with the following requirements:
   a. Mechanical crimp type terminals from recognized suppliers such as AMP brand as manufactured by TE Connectivity, or other **approved** manufacturer with a comprehensive line of terminals, connector pins and application tools.
   b. Conducting elements: Plated copper.

c. For conductor sizes No. 10 AWG or smaller:

- Insulated terminals with metal strain relief device under the insulation that is crimped onto and grips the wire insulation simultaneously with the terminal.
- The insulation material shall be rated for the expected worst-case temperature.

3. Installation:

a. Maximum of one wire in each terminal. Exceptions may be considered for devices designed for two wires.

b. Attach wire terminals and connections to the wiring with crimping tools and dies as recommended by the manufacturer and **approved**:

- Select the terminal for the wire size as recommended by the terminal manufacturer.
- Crimping tools shall be ratcheting types that ensure a complete compression.
- Maintain these tools in proper calibration and ensure that personnel using them are properly trained.

4. Prohibited terminations:

a. Hook type terminations.

b. Ring-type terminations.

c. Faston™-type (receptacle and tab) terminations, unless part of OEM components. Where permitted, use AMP PIDG or similar high-quality terminations.

d. Fork (spade) type terminations, unless specifically **approved** for applications such as relays or other devices with captive screw fasteners. Where permitted, use spring-spade type.

16.18.4 Power Wiring Terminations

Comply with the following:

1. General Applications: Bolted compression terminals manufactured by TE Connectivity (AMP brand), Thomas & Betts, or **approved** equal.

2. Special Applications:

a. Locations where rotation of termination could result in contact or unacceptable clearance: Double-bolted terminals.

b. Traction motor wire: Terminals shall be as recommended by the motor manufacturer, subject to **approval**.

3. Installation:

a. Procedures: As recommended by the terminal manufacturer.

b. Crimping tools: Ratcheting type that ensures a complete compression, and as recommended by the terminal manufacturer.

c. Terminations at heat generating devices: At the terminal, peel back insulation from the conductor a sufficient distance to prevent excessive heat from damaging insulation.

16.19 Cable Terminations

16.19.1 Multi-Pin Cable Connectors

Provide cable connectors of service proven design by manufacturers such as ITT Veam CIR Series. Connectors shall comply with the following:

1. Contacts:
    a. Removable crimp type, with a positive seating mechanism for each contact so it cannot back out of its location in the connector.
    b. Sized for the wire, as recommended by the manufacturer.
2. Strain relief: Cable clamp at the back of the connector sized for the cable jacket. Clamping on cable wires is prohibited.
3. Extension bodies: Provide where necessary to ensure that there is sufficient room to terminate cable wires while providing the seal and clamp on the cable jacket.

Adjacent connectors shall use either different inserts or different insert orientations to prevent erroneous connections.

16.19.2 Cable Connectors

Comply with the following:

1. Application:
    a. Weatherproof interior locations: Non-waterproof or waterproof IP66 connectors.
    b. Under-vehicle and exposed locations: Waterproof IP68 connectors.
2. Type: Circular or rectangular metal-shelled, positive-locking, quick disconnect, with the following features:
    a. Rated for a minimum life of 2,000 couplings before failure.
    b. Connectors shall give audible, visual, and tactile indications of full coupling.
3. Waterproof connectors shall have the following additional features:
    a. Watertight
    b. Furnished with gaskets on the front mating surface and on the back at the cable entry.
4. Installation: Seal unused connector pin positions with either connector contacts or plastic sealing plugs designed for that purpose.

16.19.3 Ethernet Cable Connectors

Comply with the following:

1. Cable-to-connector attachment shall be IP66 rated per IEC 60529.
2. Connectors directly affixed to active equipment shall be industrial Ethernet M12 type, complying with IEC 61076-2-101, with the following features:
    a. Gold plated contacts.
    b. Rated for minimum 500 mating cycles as per IEC 60512-9-1.
    c. Protected with an IP54-rated protective cover if available from vehicle interior or IP66 if vehicle exterior.
    d. Shall also meet the requirements of Section 17, Controls, Networks, and MDS.
3. Connectors mounted to bulkheads are permitted to be either Ethernet M12 or RJ45:
    a. Applies to connectors used for vehicle maintenance and not intended to be used while the vehicle is in motion.
    b. Shall be protected with an IP54-rated protective cover if available from vehicle interior or IP66 if vehicle exterior.

16.19.4 Cable Connections to Boxes and Enclosures

Comply with the following:

1. Configure cable connections to boxes and enclosures so that structural, electrical, and environmental integrity is maintained, and to facilitate removal and replacement of the box or enclosure.
2. Cable entry shall be by means of watertight sealing glands. Glands and cable terminations shall allow for cable replacement without removal of lugs, terminals, or connectors from the wires.
3. The entrance of cables in the top and bottom of equipment boxes is prohibited.

16.20 Printed Circuit Boards (PCBs)

16.20.1 General

Comply with the following:

1. Standards: Printed circuit boards shall be designed, constructed, and inspected to IPC-2221 and IPC-2222, except where more stringent requirements are noted here.
2. IPC-2221 Classes: Class 2, minimum. Class 3 requirements shall apply to all vital equipment.

16.20.2 PCB Design

Comply with the following:

1. PCBs shall be designed for ease of testability per IPC-2221, "Example of a Testability Design Checklist".
2. Traces shall be as wide as practical, with the minimum width being based on a 10°C (50°F) temperature rise.
3. Components with pins shall be mounted only on one side. Connections shall be made to the other side or internal layers via plated through-holes. Surface mount technology (SMT) devices may be mounted on both sides if part of an **approved** existing design.
4. All printed circuit boards with the same function shall be interchangeable between equipment groups without additional adjustment.
5. Printed circuit boards shall be designed for insertion and removal with power applied, except where power is removed by a switch adjacent to the card rack and except where the mechanical construction would generally prohibit removal and insertion with power applied. Where a switch is used, it shall be labeled with a warning regarding its proper use.
6. Except for the case of integrated circuits or where environmental conditions make it a necessity as **approved**, no module employing multiple components shall be made non-repairable by potting.

16.20.3 PCB Materials

Comply with the following:

1. NEMA LI 1 Type FR-4 for boards with no components with power dissipation greater than 2 watts and which are not mounted adjacent to components dissipating greater than 2 watts.
2. NEMA LI 1 Type FR-5 for other applications.
3. Printed circuit boards shall have base material minimum 1/16 in (1.6 mm) thick.

Conductor material shall be copper, shall be firmly attached to the board, and shall be resistant to blistering and peeling when heated with a soldering iron.

16.20.4 PCB Type

Comply with the following:

1. Provide PCBs of the "plug-in" type, with positive support against vibration. Single board applications of a "non-plug-in" type are subject to review and **approval**.
2. Circuit boards shall be inherently stiff or shall be reinforced to prevent damage due to vibration or handling. Circuit boards larger than 100 in² (64,520 mm²) shall be centrally stiffened unless otherwise **approved**.

16.20.5 PCB Marking

Comply with the following:

1. Component Identification:
   a. Polarity: Capacitor and diode polarity shall be marked on the component and wiring sides of the board.
   b. Orientation: Indication of transistors and thyristors orientation shall be at least two leads or one lead and a graphic symbol.
   c. Alternative schemes for component identification on circuit boards may be submitted for **approval** during design review.
2. Keying and Insertion:
   a. For integrated circuits and other multi-terminal devices, keying and insertion shall be indicated by an index mark on the component side of the board, visible with the component inserted.
   b. For IC packages, the first pin shall be identified on the wiring side of the board.

16.20.6 PCB Component Mounting

Components shall be fastened to the board in such a manner as to withstand repeated exposure to shock and vibration.

1. Large components shall be supported in addition to the solder connections.
2. Power resistors shall be mounted on standoffs so that the resistor bodies do not contact the board and shall be spaced far enough away from the board so that resistor-produced heat will not discolor or damage the board.

16.20.7 PCB IC and Device Sockets

Components shall be soldered in place and IC and device sockets are prohibited, except for components that must be removed for reprogramming or initial calibration procedures or devices that are available only for mounting in sockets.

1. Socket applications shall be subject to **approval** during design review.
2. Where **approved**, IC sockets shall comply with MIL-DTL-83502 and MIL-DTL-83734, as is applicable for the device, and shall be made of the following materials:
   a. Bodies: Diallyl phthalate, PTFE Teflon, or **approved** equal.
   b. Contacts: Beryllium copper, plated with a minimum of 0.8 µm (0.000030 in) of gold over a minimum of 1.3 µm (0.000050 in) of low stress nickel in the area of contact with IC pins.
   c. Sockets with tin-plated contacts may be used only where gold-plated sockets are not commercially available, and only with **approval**.

16.20.8 PCB Conformal Coating

Both sides of assembled printed circuit boards shall be coated with a clear insulating and protective coating material.

1. Coating shall conform to IPC-CC-830, Class 2 or better, except that all coatings shall include fluorescent indicators.
2. IC sockets, connectors, and test points shall be masked when the coating is applied.

16.20.9 PCB Keying and Interlocks

Circuit boards shall be keyed to prevent insertion into the wrong location.

Circuit boards in safety related control systems including propulsion, friction brakes, and other systems that can cause unsafe vehicle operation with a card removed, shall be interlocked through a safety circuit to disable the vehicle if a circuit board is removed.

16.20.10 PCB Connectors

Comply with the following:

1. Type: Heavy duty, high-reliability, two-part type with a history of successful service in rail applications.
2. Connectors that meet the following will be considered to comply with the Specifications:
   a. Comply with MIL-DTL-55302.
   b. Connector contact area plated with a minimum of 0.8 µm (0.000030 in) of gold over a minimum of 1.3 µm (0.000050 in) of low stress nickel.
3. Card edge connectors are prohibited.

16.20.11 Enclosures and PCB Hardware

Rack-mounted circuit boards shall plug into racks containing the mating half of the circuit board connector (see PCB Connectors section, above).

1. The circuit board rack shall mount in an enclosure conforming to the Specifications.
2. The rack, circuit board, and circuit board hardware shall be designed as an integrated system.
3. The rack and enclosure shall provide environmental and EMI shielding as required to meet the requirements of the Specifications.
4. PCBs shall be positively retained by means of keeper bars or other **approved** method. The enclosure or rack cover shall not be used to retain the circuit boards.
5. Each circuit board shall be fitted with an ejector or hand grip to assist in board removal.

6. The rack and the edge of each board, or the card ejector, shall be labeled with corresponding numbers to identify board location within the enclosure.

16.20.12 PCB Testing

Provide test points as follows:

1. Provide non-digital test points in appropriate locations on modules.

2. Provide battery negative return or local power supply common test points, as appropriate.

3. Test points shall accept a U.S. standard 2 mm (0.080 in) diameter tip plug or shall be a turret lug similar to Cambion No. 160 1026 01 05 00, or **approved** equal, with sufficient clearance to permit attachment of a standard oscilloscope probe clip.

4. Identify test points by appropriate markings.

5. Printed circuit board extenders (10 sets of each type) shall be provided by the Contractor for all rack-mounted circuit boards. The Contractor shall provide detailed maintenance and bench test troubleshooting procedures for the use of each type of extender board in the maintenance manuals including wave forms and voltages at critical locations of the circuitry.

16.20.13 PCB Schematics

Comply with the following:

1. Furnish PCB schematics to permit board-level troubleshooting, repair, and the manufacturing of replacement parts.

2. Non-repairable or "throw-away” circuit boards may be supplied only by **approval** of the Engineer. In making this request for **approval**, the Contractor shall focus on the advantages to SEPTA of this approach. Where the use of non-repairable circuit boards is granted, the Contractor shall supply to SEPTA

    a. Spare circuit boards of each type in number either equal to 15% of those employed on the equipment of one vehicle multiplied respectively by the number of vehicles supplied under this Contract; or

    b. equal to a percentage determined by the failure rate through the warranty period prorated to the number of failures predicted over 30 years of service, whichever is greater, in order to compensate for the lack of repairability.

3. If schematics cannot be supplied, furnish to SEPTA spare circuit boards of each type in number either

    a. Equal to 15% of those employed on the equipment of one vehicle multiplied respectively by the number of vehicles supplied under this Contract; or

    b. Equal to a percentage determined by the failure rate through the warranty period prorated to the number of failures predicted over 20 years of service, whichever is greater, in order to compensate for the lack of repairability.

16.21 Contract Deliverables Requirements List (CDRL)

16-1 Recommended Cleaning Agents
16-2 Certification of No Prohibited Materials
16-3 Proposed Materials Not Covered by Specification or Standard
16-4 Safety Data Sheets (SDS)
16-5 Fasteners Design Package
16-6 Stainless Steel Test and Inspection Plan
16-7 Carbon and High-Strength Low-Alloy (HSLA) Steel Selection
16-8 Structural Steel Test and Inspection Plan
16-9 Casting Selection
16-10 Casting Qualification Test Report
16-11 Casting NDT Inspection Sampling Frequency
16-12 Aluminum Test Reports
16-13 Weld Test Plan
16-14 Straightening
16-15 Flammability, Smoke Emission, and Toxicity Design Package
16-16 Waiver of FST Type Testing
16-17 Paint Performance Test
16-18 FRP Performance Test Certificates
16-19 Conduit and Raceways Design Package
16-20 Junction Box Design Package
16-21 Wire and Cable Design Package
16-22 Wire and Cable Connections Design Package

16.22 CDRL Detail

Submit the following in accordance with Section 19, Program Control and Quality Assurance:

16-1 Recommended Cleaning Agents:

1. Each material exposed to normal cleaning: Manufacturer's recommended cleaning agent.
2. Each cleaning agent: Safety Data Sheet (SDS).

16-2 Certification of No Prohibited Materials:

1. List of prohibited materials, and certification that none are present on vehicles.

16-3 Proposed Materials Not Covered by Specification or Standard:

1. Material, identified by commercial trademark, name, and address of Supplier.
2. Description and technical data specifications of material composition.

16-4 Safety Data Sheets (SDS):

1. Submit as one complete package including an SDS for each chemical material used in the manufacture of the vehicle.

16-5 Fasteners Design Package:

1. Matrix listing each type of fastener used on the vehicle. Furnish the following information:

    a. Fastener type
    b. Manufacturer
    c. Base material and plating or finish
    d. Size(s)
    e. Property class, grade, strength
    f. Indication of application for structural and safety-related fasteners
    g. Indication of location for fasteners used where there are location-specific requirements
    h. Indication of application for fasteners used where there are application-specific requirements

2. Manufacturer's data for each type of fastener, with sufficient information to demonstrate compliance with the Specifications.

3. Plating type used for high strength fasteners.

4. Alternate plating or coating system (if proposed):

    a. Qualification data for each process used at each Supplier applying proposed coating, including the following:

        - Coating manufacturer's product data including required thickness
        - ASTM B117 test results from an accredited third party laboratory
        - Documentation of torque/tension characteristics
        - A statement from the coating manufacturer regarding the propensity for the coating process to cause hydrogen embrittlement of the fastener during coating

5. Structural threaded fasteners: Sufficient information to demonstrate compliance with the requirement for coordination of nut strength with bolt strength to prevent undetected internal thread stripping, including calculations if required.

6. Safety-related fasteners: Proposed sample quantities to be used for production lot testing.

16-6 Stainless Steel Test and Inspection Plan:

1. Submit before purchasing stainless steel to be used in welded applications.

2. Purpose: For acceptance of stainless steel.

    a. Austenitic stainless steels: Include frequency of submittal of certifications in accordance with ASTM A666 and frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A262.
    b. Ferritic stainless steels: Include frequency of submittal of checks for susceptibility to intergranular corrosion in accordance with ASTM A763.

16-7 Carbon and High-Strength Low-Alloy (HSLA) Steel Selection:

1. Submit for steel grade and application.

16-8 Structural Steel Test and Inspection Plan:

1. Submit before purchasing structural steel.
2. Include provisions for submission of reports and certification to SEPTA for each shipment in accordance with the applicable requirements of this Section and specified CGHAZ impact tests.

16-9 Casting Selection:

1. Submit for casting composition, heat treatment, and design best suited for the intended application.

16-10 Casting Qualification Test Report:

1. If the casting selected for qualification fails to qualify, include a plan of action with details of how failed material will be handled.

16-11 Casting NDT Inspection Sampling Frequency:

1. NDT inspection plan shall include Magnetic Particle, Dye Penetrant, and Radiographic testing.

16-12 Aluminum Test Reports:

1. Copies of all test reports for sheet, extrusion, and forgings used in the vehicle structure.

16-13 Weld Test Plan:

1. Submit proposed test plan which shall include most critically loaded welds.

16-14 Straightening:

1. Qualifications for the personnel performing straightening to demonstrate that they are both qualified and experienced in performing the proposed procedures.
2. Specification for material being straightened.
3. Straightening procedure for each type of straightening proposed.
    a. Include parameters for what constitutes major and minor nonconformities, and the procedures for each.
    b. Include procedures for inspection to be performed after straightening.
    c. Include procedures for nondestructive tests to be performed after straightening.

16-15 Flammability, Smoke Emission, and Toxicity Design Package:

1. Submit a matrix including the following during design review:
    a. Total weight of all materials
    b. Where material is used
    c. Flammability, smoke emission, and toxicity test identity
    d. Test facility

e. Test requirements
f. Test results
g. Nature and quantity of the products of combustion
h. Supplier's name

2. Submit test reports containing the following information for all materials tested:

   a. Test Performed
   b. Date Tested
   c. Test Facility
   d. Test Results
   e. Toxicity

3. Prepare and submit a Fire Safety Analysis of the design and materials of construction of the vehicle as part of the design phase of the Contract prior to construction of the first Pilot Vehicle.

   a. The fire safety analysis shall consider likely fire scenarios and the time available for passengers to evacuate the railcar to a place of safety.

16-16 Waiver of FST Type Testing:

1. Submit in writing as one package, including each type material for which a waiver is requested.

2. Include the total weight of the material to be used, the location of the material and its distribution in the vehicle.

3. Furnish flammability, smoke emission, and toxicity test reports for each material.

16-17 Paint Performance Test:

1. Paint Performance Test Procedure:

   a. Include a list of each type of paint and powder used on the vehicle with its location on the vehicle and sufficient identifying information so that it can be cross referenced with the paint design package specified in Section 16, Materials and Workmanship.
   b. Include specified test criteria
   c. Include step-by-step test procedures for each specified test

2. Paint Performance Test Report:

   a. Submit as one package including test results for each type of paint and powder used on the vehicle.
   b. Include sufficient test data to demonstrate compliance with the Specifications.
   c. Indicate whether each type of paint or powder passed or failed each test.

16-18 FRP Performance Test Certificates:

1. For each FRP item, furnish an independent laboratory test certificate stating that the production FRP material complies with the specified strength requirements when tested in accordance with the specified standards.

16-19 Conduit and Raceways Design Package:

1. Manufacturer's data for each type of proposed conduit.

2. Manufacturer's data for each type of proposed wireway, and indicate where it is proposed for use.

16-20 Junction Box Design Package:

1. Submit the proposed product line of junction boxes.

16-21 Wire and Cable Design Package:

1. Matrix showing each type of wire and cable proposed for use on the vehicle, and indicate the application(s) for which it will be used.

    a. Manufacturer's data for each type of wire and cable in the matrix.
    b. Number and name of the standard or standards with which each type of wire or cable complies.

2. Sample of each type of wire and cable proposed, including wire that is part of equipment proposed for use on the vehicle. Samples shall be 30 cm (12 in) long.

3. Three copies of certified type test documentation for each size and type of wire and cable proposed.

4. Proposed wire and terminal designation system:

    a. Manufacturer's data for wire, cable, and terminal markers
    b. Printed samples of wire, cable, and terminal markers

5. Manufacturer's data for wire ties and clamps

6. Details of proposed spare wires in each harness or group of wires.

7. Proposed terminations for spares

16-22 Wire and Cable Connections Design Package:

1. Proposed terminations product line.

2. Manufacturer's data on termination crimping tools

3. Specific application terminations:

    a. Power wire terminations
    b. Traction motor wire terminations

c. Ethernet terminations

4. Manufacturer's data for each type of cable connector.

16.23 Referenced Standards

The following standards are referenced in this Section:

29 CFR 1910.119 Appendix A	List of Highly Hazardous Chemicals, Toxics and Reactives (Mandatory)
29 CFR 1910.1200 (g)	Safety data sheets.
49 CFR 238	Passenger Equipment Safety Standards
49 CFR 238.103 (c)	Fire safety analysis for procuring new passenger cars and locomotives
AAMA 611	Voluntary Specification for Anodized Architectural Aluminum
AAMA 2605	Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix)
AAR M-201	Castings, Steel
AAR M-202	Truck Bolsters, Cast or Structural--Design and Testing
AAR M-203	Truck Side Frames, Cast Steel--Design and Testing
AAR RP-585	Wiring and Cable Specification
AAR RP-587	Wire and Cable Insulating Material—Silicone Rubber Insulated
Aluminum Association	Aluminum Design Manual
Aluminum Association	Aluminum Standards and Data
ANSI/ASNT CP-189	ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel
ANSI C80.1	American National Standard for Electrical Rigid Steel Conduit (ERSC)
APTA PR-E-RP-002-98	Recommended Practice for Wiring of Passenger Equipment
APTA PR-PS-RP-005-00	Recommended Practice for Fire Safety Analysis of Existing Passenger Rail Equipment
ASME B4.1	Preferred Limits and Fits for Cylindrical Parts
ASME B31.1	Power Piping, ASME Code for Pressure Piping

ASME BPVC-VIII-1	Boiler and Pressure Vessel Code, Section VIII: Division 1 Rules for Construction of Pressure Vessels
ASME BPVC-IX	Boiler and Pressure Vessel Code, Section 9, Welding, Brazing, and Fusing Qualifications
ASNT SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing
ASTM A6/A6M	Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A36/36M	Standard Specification for Carbon Structural Steel
ASTM A240/240M	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A449	Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
ASTM A480/A480M	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
ASTM A488/A488M	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
ASTM A502	Standard Specification for Rivets, Steel, Structural
ASTM A568/A568M	Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
ASTM A588/A588M	Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
ASTM A606/A606M	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A666	Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
ASTM A710/A710M	Standard Specification for Precipitation–Strengthened Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Structural Steel Plates

ASTM A763	Standard Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
ASTM A874/A874M	Standard Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service
ASTM A923	Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels
ASTM B26/B26M	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B33	Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes
ASTM B85/B85M	Standard Specification for Aluminum-Alloy Die Castings
ASTM B108/B108M	Standard Specification for Aluminum-Alloy Permanent Mold Castings
ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B209/B209M	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B221	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B247	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
ASTM B298	Standard Specification for Silver-Coated Soft or Annealed Copper Wire
ASTM B355	Standard Specification for Nickel-Coated Soft or Annealed Copper Wire
ASTM B557	Standard Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B594	Standard Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products
ASTM B633	Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM D256	Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
ASTM D618	Standard Practice for Conditioning Plastics for Testing
ASTM D638	Standard Test Method for Tensile Properties of Plastics

ASTM D648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D785	Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
ASTM D790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D952	Standard Test Method for Bond or Cohesive Strength of Sheet Plastics and Electrical Insulating Materials
ASTM D2583	Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
ASTM D3159	Standard Specification for Modified ETFE Fluoropolymer Molding and Extrusion Materials
ASTM D3363	Standard Test Method for Film Hardness by Pencil Test
ASTM D5402	Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs
ASTM D5420	Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)
ASTM E94/E94M	Standard Guide for Radiographic Examination
ASTM E165/E165M	Standard Practice for Liquid Penetrant Testing for General Industry
ASTM E340	Standard Practice for Macroetching Metals and Alloys
ASTM E446	Standard Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
ASTM E662	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
ASTM E709	Standard Guide for Magnetic Particle Testing
ASTM E1030/E1030M	Standard Practice for Radiographic Examination of Metallic Castings
ASTM E1742/E1742M	Standard Practice for Radiographic Examination

ASTM F519	Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
ASTM F606/F606M	Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
ASTM G101	Standard Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels
AWS B2.2/B2.2M	Specification for Brazing Procedure and Performance Qualification
AWS C3.4M/C3.4	Specification for Torch Brazing
AWS D1.1/D1.1M	Structural Welding Code - Steel
AWS D1.2/D1.2M	Structural Welding Code - Aluminum
AWS D1.3/D1.3M	Structural Welding Code - Sheet Steel
AWS D1.6/D1.6M	Structural Welding Code - Stainless Steel
AWS D15.1/D15.1M	Railroad Welding Specification for Cars and Locomotives
AWS D17.2/D17.2M	Specification for Resistance Welding for Aerospace Applications
AWS Welding Handbook	
BSS 7239	Test method for Toxic Gas Generation by Materials on Combustion
EN 50343	Railway applications - Rolling stock - Rules for installation of cabling
EN ISO 9606-1:	Qualification testing of welders - Fusion welding - Part 1: Steels
EN ISO 9606-2	Qualification test of welders - Fusion welding - Part 2: Aluminum and aluminum alloys
Federal Specification MMM-A-181	Adhesives, Phenol, Resorcinol or Melamine Base
ICEA S-95-658	Power Cables Rated 2000 V or Less for the Distribution of Electrical Energy
IEC 60512-9-1	Connectors for electronic equipment - Tests and measurements - Part 9-1: Endurance tests - Test 9a: Mechanical operation
IEC 60529	Degrees of protection provided by enclosures (IP Code)

IEC 61076-2-101	Connectors for electronic equipment - Product requirements - Part 2-101: Circular connectors - Detail specification for M12 connectors with screw-locking
IFI-543	Test for Evaluating the Torque-Tension Relationship on Both External and Internal Metric Threaded Fasteners
IFI. 2013. Torque Book for Fasteners	
IEEE Std 16	IEEE Standard for Electrical and Electronic Control Apparatus on Rail Vehicles
IEEE 1202	Standard for Flame-Propagation Testing of Wire & Cable
ISO 273	Fasteners -- Clearance holes for bolts and screws
ISO 898-1	Mechanical properties of fasteners made of carbon steel and alloy steel -- Part 1: Bolts, screws and studs with specified property classes -- Coarse thread and fine pitch thread
ISO 898-2	Mechanical properties of fasteners made of carbon steel and alloy steel -- Part 2: Nuts with specified property classes -- Coarse thread and fine pitch thread
ISO 156xx series (15607 to 15614)	Specification and qualification of welding procedures for metallic materials
MIL-DTL-25427	Detail Specification: Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect
MIL-P-23469	Pin-Rivet, Grooved and Collar, Grooved Pin-Rivet, Swage-Locked (Lockpin), General Specification for
MIL-PRF-83282	Performance Specification: Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, NATO Code Number H-537
NAS 410	NAS Certification and Qualification of Nondestructive Test Personnel
NASM21044	Nut, Self-Locking, Hexagon, Regular Height, 250 degrees F, 125 ksi Ftu and 60 ksi Ftu
NEMA HP 3	Insulated High-Temperature Hook-Up Wire, Types ET (250 V), E (600 V), and EE (1,000 V)
NEMA LD 3	High-Pressure Decorative Laminates (HPDL)
NFPA 70	National Electrical Code
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems
NIST PS 1	Structural Plywood

SAE AMSC 7438	Core Material, Aluminum, for Sandwich Construction
SAE J429	Mechanical and Material Requirements for Externally Threaded Fasteners
SAE J995	Mechanical and Material Requirements for Steel Nuts
SAE USCAR 7-1	De-embrittlement Verification Test
SMP 800-C	Toxic gas generation from material combustion/BombardierSSPC-Paint-25 Zinc Oxide, Alkyd, Linseed Oil Primer for Use Over Hand Cleaned Steel (Type I and Type II)
TIA 569	Telecommunications Pathways and Spaces
UL 1685	Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

END OF SECTION

Table of Contents

17.1 General

17.1.1 Scope

This Section includes the following:

1. Requirements for the vehicle control system specified in this and other sections.

2. Requirements for the vehicle network and monitoring and diagnostic system.

3. Cybersecurity requirements.

See Section 2, Design and Performance Criteria, Section 5, Operator's Cab Controls, Section 9, Electrical Equipment, and Section 13, Vehicle Communication Systems, for additional or related control requirements.

17.1.2 Electronic Control Equipment Configuration

Comply with the following:

1. Segregate electronic control equipment both physically and electrically from power equipment.

2. Galvanically isolate control circuitry and control voltage sources from power circuitry and high-voltage sources via transformers.

3. Provide dedicated power supplies for control systems that are transformer isolated and powered from the dc low-voltage power supply (LVPS).

17.2 Control Logic Units

17.2.1 General

Comply with the following:

1. Each vehicle system shall have dedicated network-connected controls to achieve all functionality specified in this Section and other sections of the Specifications. Provide diagnostics and fault logging, connections, and firmware for PTUs.

2. The control logic units shall include user-programmable operating characteristics. Control programs shall be stored in field-updateable, non-volatile memory.

3. All connections to low-voltage dc circuits shall have galvanic isolation.

17.2.2 Vehicle Control Unit

Provide a control unit, designated as the vehicle control unit (VCU):

1. Purpose: To manage all communication between vehicle systems, monitor system states, display required information on the MDS TOD(s), and similar functions.

2. Alternate to VCU: May be proposed to SEPTA, such as the propulsion system providing the VCU function.

17.2.3 Monitoring and Fault Recording Capability

Comply with the following:

1. Control logic units shall have self-diagnostics, monitor status and faults of internal and external devices, and continuously monitor critical parameters (Local Diagnostic and Test System (LDTS)).
2. LDTSs shall be integrated into the Monitoring and Diagnostic System (MDS) specified below.
3. The control logic unit and related software and devices shall be sufficiently responsive to detect and remedy erroneous or potentially damaging conditions such that equipment damage is prevented or minimized.

17.3 Control Signals

17.3.1 General

Comply with the following:

1. The design decision for each signal shall be made in accordance with the Safety and Hazard analyses required in Section 2, Design and Performance Criteria.
2. All discrete control signals shall be redundant.
3. Where redundant control signal wiring is used, the redundancy scheme shall use physical redundancy, be routed in separate paths, and be interconnected with separate connectors.
4. All communications within a vehicle and between vehicles of a train shall be transmitted by physical wires; wireless data transfer is prohibited.
5. The status of control signals may be monitored by the vehicle network controllers specified below. However, the discrete control signals shall predominate, and conflicts shall be flagged as errors.

17.3.2 Required Discrete Control and Status Signals

Provide the following signals, at a minimum, and configure as Type 1 interfaces as defined in IEEE Std 1475 in regard to propulsion and braking:

1. Cab or Vehicle activation status
2. Emergency brake control
3. Door Interlock (locked and closed) status
4. Door Enable control
5. Door Open control

6. No Motion status
7. Propulsion mode control
8. Brake mode control
9. Snow brake control
10. Track brake control
11. Friction brake released status
12. Friction brake applied status
13. Forward mode control
14. Reverse mode control
15. Sanding control
16. Spin/Slide control

17.3.3 Special Requirements for Door Control and Status

Configure door control and status signals in a completely separate left/right side of vehicle configuration as indicated in Section 6, Passenger Doors.

17.3.4 Propulsion and Braking Controls

Propulsion and braking controls may be implemented through one of the following control schemes:

1. Mode A:
    a. Propulsion and braking controls shall be through discrete and vital wires, and not through network interfaces. This extends to all control elements of propulsion and braking equipment.
    b. Monitoring functionality will be required and shall connect to the MDS through the PCN.
2. Mode B:
    a. Dedicated redundant PCN network hardware completely segregated from all other on-vehicle networks for all propulsion and braking controls.
    b. This design be demonstrated to be fundamentally cybersecure with minimal upkeep by SEPTA staff.
    c. Equipment monitoring and reset capability shall be possible from MDS, but in a way that prevents data from flowing into PCN from MDS through devices such as I/O modules or rail data diodes.

17.3.5 Fault Status Report to MDS

The following non-exhaustive categories of fault statuses shall be reported to the MDS for logging or display on MDS TOD(s), with further fault reporting to be developed as part of design review:

1. Propulsion Faults:
    a. Propulsion System equipment or module failure
    b. Propulsion System Degraded Mode
    c. OCS voltage too high or too low
    d. HSCB Open State
2. Brake System Faults:
    a. Brake equipment failure or cutout status
    b. Braking degraded mode
    c. Braking fault leading to reduced propulsion performance due to propulsion inhibit state (as in Section 10, Propulsion System and Control, and Section 12, Friction Brake System)
3. Network Faults
4. MDS Faults:
    a. Server Faults
    b. MDS TOD Faults
5. Train-to-Wayside Communication Faults
6. HVAC Faults
7. Door Faults
8. Auxiliary Power Faults:
    a. LVPS Faults
    b. Tripped Breakers
    c. HSCB or Fuse Open State
9. CBTC Faults (one-way data traffic through data diode or equivalent alternate **approved** by Engineer)
10. Collision Avoidance System Faults
11. Event Recorder Faults

12. Closed Circuit Television (CCTV) Faults:
    a. CCTV Camera Faults
    b. CCTV Recorder Faults
13. Intercom Faults:
    a. Cab Intercom
    b. Passenger Emergency Intercom
14. Automatic Passenger Information System (APIS) Faults
15. Public Address System Faults
16. Automatic Passenger Counting (APC) Faults
17. Infotainment Faults (through discrete I/O due to non-permitted network interfaces)
18. Passenger Wi-Fi Faults (through discrete I/O due to non-permitted network interfaces)
19. Fare Collection Faults (through discrete I/O due to non-permitted network interfaces)
20. Voice Radio Faults (through discrete I/O due to non-permitted network interfaces)

17.3.6 Discrete Trainlines

Provide a minimum of the following discrete trainlines, with other trainlines as dictated by safety analysis:

1. Emergency Brake
2. Door Enable
3. All Doors Closed and Locked

17.4 Vehicle Data Network

17.4.1 General

All vehicle system control logic units shall communicate with each other and the main VCU via all-Ethernet, IP-based data networks.

17.4.2 Network Standards

Comply with the following:

1. The main vehicle networks shall conform to TCN (Train Communication Network), in accordance with IEC 61375. The following network types are permitted:
    a. ECN (Ethernet Consist Network): IEC 61375-3-4

b. ETB (Ethernet Train Backbone): IEC 61375-2-5

c. WCN (Wayside Communications Network): IEC 61375-2-6

2. Alternative networking technologies may be proposed for **approval** that provide equivalent performance and reliability.

3. See Section 13, Vehicle Communication Systems, for communications network requirements.

17.4.3 Network System Redundancy

Comply with the following:

1. Use a partial mesh topology and other techniques to minimize the effects of single-point network failures on the remaining system.

2. Data networks shall be single-point fault tolerant and be able to maintain communications between connected nodes in the event of a single open or short circuit. Fault recovery shall be automatic to the maximum extent possible.

3. Establish redundant links between managed switches and routers using Rapid Spanning Tree Protocol (IEEE Std 802.1D) or Shortest Path Bridging (IEEE Std 802.1Q) to achieve a convergence time of no more than 6 seconds after a link failure or topology change.

4. Unmanaged switches are prohibited.

5. Network protocols used shall be non-proprietary, such as Rapid Spanning Tree Protocol (IEEE Std 802.1D), Open Shortest Path First (RFC 5340), and Shortest Path Bridging (IEEE Std 802.1Q).

17.4.4 Network Requirements

Comply with the following:

1. The network system shall use an open design that is either non-proprietary or available from multiple sources. Network components and transceivers shall be available from multiple sources.

2. Network protocol shall be structured in a manner similar to the ISO/OSI communication model. All layers other than the application layer shall be transparent to the various vehicle system suppliers with the exception of network diagnostics.

3. Communication related to real time control, such as propulsion control, shall be prioritized to the extent that anomalies in system stability and operation are prevented.

4. Calculated peak and average traffic levels shall not exceed 30% of the recommended peak and average traffic levels. Train-to-wayside communications shall not exceed 50% of recommended peak levels, with QOS for prioritization of more critical traffic. Actual peak and average traffic levels measured under Section 15, Testing, shall not exceed 35% of the recommended peak and average traffic levels.

5. Protocols shall include error detection and retransmission. Each node on the network shall collect summary statistics regarding current and historical error rates and make that information available through the Monitoring and Diagnostic System specified below.

6. Network wiring shall be physically isolated from sources of EMI.

7. The main network shall be fault tolerant, such that loss of connections to systems does not affect the connections of other systems to the network.

8. Physical designs shall presume that there are differences in the ground reference level between vehicles and within vehicles. Alternative shielding and grounding schemes may be proposed with justification.

9. Ethernet connectors shall be either four-pin M12 D-coded or eight-pin M12 X-coded, complying with Section 16, Materials and Workmanship; the use of 8P8C connectors (commonly referred to as RJ45) is prohibited. All equipment mounted network connectors shall be M12.

10. Ethernet cabling shall be Category 6 (Cat 6) or better shielded twisted pair, complying with Section 16. The same type of Ethernet cabling shall be used throughout the vehicle.

11. All network nodes and end devices shall have provisions to allow the system to know the type of device and physical location of the device without any configuration when devices are replaced.

12. Network nodes performing like-functions shall be interchangeable between locations.

13. Communications shall use IP unicast and multicast as appropriate. The use of broadcast messages other than IP address resolution and assignment (e.g. ARP and DHCP) shall be approved by the Engineer on a case-by-case basis.

14. Network switches used for Communications System functionality shall support Power Over Ethernet (PoE) on all ports, including spares.

15. Functional Networks:

    a. Different communication functions (functional networks) shall be isolated from each other separate physical networks. At a minimum, provide the following distinct functional networks:

        - Propulsion Control Network 1 (PCN1)
        - Propulsion Control Network 2 (PCN2)
        - Monitoring and Diagnostics
        - Communication Systems (see Section 13, Vehicle Communication Systems)
        - Wayside Communications

    b. In addition, provision infrastructure for the installation of the following standalone third-party networks:

        - Fare Collection
        - Public Wi-Fi and Infotainment

  c. Interconnections between functional networks shall be done through the use of a firewall with a whitelist ruleset where any communication not explicitly allowed is blocked by default, or through an Application Layer Gateway (ALG).

16. Provide a PTU Universal Service Port (USP) or ports in each cab to allow a PTU to meet all of the requirements in Section 19, System Support. Provide a sufficient number of dedicated PTU ports for each isolated network segment to ensure all necessary functionality while ensuring necessary network isolation.

17. Spare Ports per Network:

    a. PCN1 and PCN2: Two in A-Car and two in B-Car

    b. Monitoring and Diagnostics: Two per vehicle segment

    c. Communications Systems: Four per vehicle segment

17.4.5 Protocol Analyzer PTU

Comply with the following:

1. Provide a real-time protocol analyzer PTU to perform detailed diagnostics and real-time monitoring of all network activity for all of the networks provided. All networks shall support use of the PTU.

2. The PTU shall be able to decipher train communications to the application layer.

    a. The PTU shall furnish raw data definitions as defined in the Interface Control Document (ICD) (e.g. by using a Wireshark dissector). For encrypted communications, an alternate method of inspecting the traffic shall be provided off the vehicle with captured traffic.

3. The PTU shall be able to view the data of encrypted communications that are used for vehicle control and operation (not used solely for PTU interaction).

    a. Alternately, provide a centralized monitor port that outputs all encrypted subsystem traffic used for vehicle control and operation (not used solely for PTU interaction) in a decrypted read-only form.

    b. Access to this output data shall first require authenticating as a maintenance-level user account.

    c. The read-only capability of this port shall be provided via a physical-layer data diode that blocks return traffic.

4. See Section 19, System Support, for additional PTU details.

17.4.6 Propulsion Control Networks (PCN)

Comply with the following if network-based propulsion controls are used:

1. The PCN data network used for train control purposes shall follow the Type III signals as defined in IEEE Std 1475.

2. The data format employed shall conform to the Train Real Time Data Protocol (TRDP) as defined in IEC 61375-2-3 and shall use the optional safety layer.

3. There shall be two PCN networks (PCN1 and PCN2) that provide physically diverse redundant information from end to end.

   a. The vehicle-level may be implemented using two physically separate ECNs, using separate Layer 3 subnets, or using one ECN with separate VLANs.

   b. The train-level may be implemented using two physically separate ETBs or using one ETB with link aggregation and VLANs.

      - If only one ETB is used with link aggregation, each PCN VLAN shall use distinct physical links in the aggregate link.

4. All end devices used for train control purposes (connected to the PCN network) shall be dual-homed with each connection going to a different network node and associated with a different network, subnet, or VLAN.

5. All end device PCN signals shall be sent in parallel using the redundant PCN networks where each connection of the dual-homed end device sends out duplicate information.

6. If the PCN is implemented on a shared physical infrastructure using VLANs or Layer 3 subnets, the PCN VLAN/subnet shall be given the highest priority using Quality of Service (QoS) as defined in IEEE Std 802.1Q. See NIST SP 800-82.

17.4.7 Monitoring and Diagnostics Network (MDN)

Comply with the following:

1. The data format employed for communications, other than with a PTU, shall conform to TRDP as defined in IEC 61375-2-3. Alternative communication formats may be proposed for **approval** (e.g. SNMP v3).

2. MDN network shall be used for MDS functionality

17.4.8 Communication Systems Network (CSN)

Comply with the following:

1. The data format employed for communications other than with a PTU, audio, or video shall conform to TRDP as defined in IEC 61375-2-3. Alternative communication formats may be proposed for **approval** (e.g. SNMP v3, HTTPS).

2. Audio and video data shall use IETF/RFC-recognized IP services, such as RTP and RTCP.

3. If installed on the vehicle, public Wi-Fi or infotainment functionality shall not access the CSN.

4. The CCTV system is to be standalone from all other networks onboard the vehicle, including the CSN, but shall connect to a dedicated port on the WCN for train-to-wayside communications.

17.4.9 Towing Mode Network Configuration

The network shall support the network and communications requirements during towing operations as specified in Section 5, Operator's Cab Controls, Section 13, Vehicle Communication Systems, and Section 21, Communications Based Train Control.

17.4.10 Wayside Communication Network (WCN)

17.4.10.1 General

Provide wireless communication from the vehicle to the wayside for transmission of data to the vehicle maintenance workstation(s) at SEPTA facilities:

1. The data format employed shall use an IETF/RFC-recognized IP service or TRDP as defined in IEC 61375-2-3 while conforming to IEC 61375-2-6 for onboard-to-ground communication.
2. Only devices that must communicate their information to the wayside are permitted to be on this network. Alternately, the WCN may use a vehicle-borne data diode or train-to-wayside broker that acts as an ALG to isolate all vehicle-borne devices from the wayside.

17.4.10.2 WCN Data Radio

To support the requirements of the WCN, provide a data radio that conforms to interface requirements for SEPTA wayside data radios. The onboard data radio shall be a Digi WR44 RR or **approved** equal. Provide and install an Advantech Network Switch (EKI-770G-4FI-AE) or **approved** equal at the WCN Data Radio location to provision for additional connections.

17.4.10.3 Vehicle Status and Health Data

Push MDS maintenance logs and real-time vehicle status to maintenance servers and workstations on the wayside, depending on availability of WCN radio connectivity, in a cybersecure fashion to support the following functionality:

1. Maintenance faults for all subsystems, including the following additional metadata:
    a. Vehicle speed
    b. Master Controller position
    c. Emergency Brake application status
    d. Vehicle location
2. Ensure that remote troubleshooting functionality can have no impact on safety critical onboard systems.
3. Arrange the data fields to be accessed individually.
4. Place the data in a memory buffer, updated at agreed intervals, for asynchronous retrieval.

5. Examples of desired data fields include the following, but are not restricted to:
    a. Vehicle location via GPS
    b. Passenger counts, from the APC system
    c. Vehicle mileage
    d. Vehicle faults, using agreed codes
    e. Vehicle incidents, such as passenger emergency door access, and MB/EB applications
6. Additionally, log last-known vehicle location. With continuous WCN connectivity, it shall be possible to always query vehicle location from wayside servers and workstations.

17.4.10.4 WCN Permitted Data Traffic

The WCN shall support only the following data traffic, with all other traffic blocked, to maximize cybersecurity:

1. One-way maintenance log transfer from vehicle MDS to wayside monitoring server(s)
2. One-way vehicle location reporting from vehicle MDS to wayside monitoring server(s)
3. One-way APC data transfer from vehicle APC to wayside APC server(s)
4. One-way real-time vehicle health status reporting from vehicle MDS to wayside monitoring server(s)
5. One-way offload of vehicle energy consumption data from vehicle MDS to wayside monitoring server(s)
6. One-way message database update from wayside servers to vehicle
7. One-way upload of database of prerecorded PA announcements from wayside servers to vehicle
8. One-way upload of firmware and software updates from wayside servers to CSN-connected systems. Firmware updates shall only be uploaded to the vehicle, but install is to be performed locally.
9. Time synchronization data from wayside to CCTV system, which is standalone from other onboard networks.

17.4.11 Cybersecurity

The requirements in this section apply to all hardware, software, and firmware provided under this Contract. These requirements apply to all products, whether resident within a microprocessor-controlled subsystem, provided as part of test or interface equipment, provided for the purpose of post-download data analysis and processing, or incorporated within training technology and manuals, and Bench Test Equipment (BTE).

Comply with the following:

1. The vehicle networks and systems shall be designed to be fundamentally cybersecure as per best practices. See NIST SP 800-53 for Cybersecurity Controls, SP 800-82 for Industrial Control Network Cybersecurity, NIST SP 800-160 for Systems Security Engineering, as well as IEC-62443 for overall system architecture.

2. The on-vehicle network shall be designed with the assumption that the WCN data radio is an inherently vulnerable medium that may at some point be breached. Communications between the WCN data radio and onboard systems shall be tightly controlled and risks mitigated and shall be compliant with IEC-62375-2-6.

3. Unauthorized devices shall not be allowed to communicate on any network given physical access (e.g. IEEE 802.1X). See NIST SP 800-53 Rev 4 (IA-3) Device Authentication. Alternatives are subject to **approval**.

4. Network node physical ports not used for vehicle operation or maintenance shall be disabled. Implement a method to disable maintenance ports when not in use (e.g., PTU).

5. Apply ingress/egress rate limiting on end-device ports as appropriate.

6. All systems shall employ the principle of least privilege to allow access where a user account permission hierarchy is provided, to enable each user account access only to the requisite capabilities.

   a. User accounts shall be configurable by SEPTA including the addition and deletion of user accounts and changing of user account passwords including root accounts.

   b. Configure each component to operate using the principle of least functionality so that each subsystem shall be given only those permissions needed for it to perform its intended function.

   c. Provide a centralized user account management tool to allow fleetwide modifications, additions, and deletions of user accounts in a secure manner demonstrated to be compliant to the recommendations of the National Institute of Standards (NIST).

      - If a vehicle is not in communication with the tool when an update to user accounts is issued, the update shall be scheduled to happen automatically when the vehicle next connects to the tool.

      - The tool shall furnish feedback as to the update progress to all applicable vehicles, so as to allow an administrator to verify that all vehicles received the update.

7. All user logins shall be authenticated and authorized by the end device prior to allowing system access. Logins that are verified only on a PTU are prohibited.

8. Passwords:

   a. Communication that involves the transmittal of passwords or session tokens over a network (e.g., a PTU login or file transfer) shall use an encrypted connection (e.g., HTTPS, FTPS, SFTP).

   b. Passwords shall use both salting and peppering mechanisms to make the hash version of the password, as referenced in Item c below, more secure.

   c. Passwords shall be stored in a one-way hashed format in compliance with NIST requirements from IA-5 (Authenticator Management) in NIST SP 800-53 Rev. 5, and from industry hash standards. Deprecated hashing protocols are prohibited (e.g., SHA1). Identify the most applicable industry hash standard and submit to SEPTA for **approval.**

   d. Passwords shall not be logged.

   e. Passwords shall not be stored in clear text.

   f. Passwords shall not be hardcoded into software or scripts.

   g. Any communication that involves the transmittal of password or session tokens over a network (e.g., a PTU login or file transfer) shall use an end-to-end encrypted connection (e.g., HTTPS, FTPS, SFTP).

   h. All factory passwords that may be publicly available shall be replaced by a password that meets the above requirements prior to delivery of the product to SEPTA.

9. Systems shall implement an approach for collecting and storing security log files.

   a. Security log files shall contain timestamped events to allow audits and investigations, similar to syslogs, as defined by RFC 5424.

   b. Security log files shall be read-only for all user accounts, including administrator accounts, and furnish a method to validate log integrity.

   c. Logging capabilities provided by the Contractor shall be configurable by SEPTA and support security auditing requirements.

   d. The approach shall cover the following events, at a minimum (as appropriate to their function):

      - Information requests and device responses
      - Successful and unsuccessful authentication and access attempts
      - Account changes
      - Privileged uses

   e. Store security log files in the MDS specified in Section 17, Controls, Networks, and MDS

f. Transfer security log files in the vehicle to SEPTA's wayside central Security Information Management (SIM) system via the Wayside Communication Network (WCN). Details of SEPTA's SIM will be provided by SEPTA during the design review phase.

g. Time stamp audit trails and log files in Coordinated Universal Time (UTC).

h. Provide security protection of log files, both stored in MDS, and stored on the wayside, with confidentiality and integrity.

10. Events in the security log files shall comply with the Log Management requirements specified under NIST SP 800-92.Systems shall provide a way to access a system, given physical access to a device, to prevent SEPTA from being locked out of a system if passwords are lost. This action shall be logged and auditable. The proposed method is subject to **approval.**

11. Encryption and authentication schemes used shall be approved for active use (e.g., not superseded or deprecated) by their respective governing bodies. Identify the most applicable cryptography standard and submit to SEPTA for **approval.** Protocols with known flaws or broken security are prohibited.

12. Vehicle systems shall be designed with planned future security improvement capabilities so that for the life of the vehicles, any protocols used that become deprecated can be upgraded or replaced.

13. Produce a Software Configuration Item Summary Table as per Section 18, Systems Software and Engineering. This table shall be used to monitor for software vulnerabilities.

    a. Prior to vehicle acceptance, monitor the NIST National Vulnerability Database (NVD) Common Vulnerabilities and Exposures (CVE) list for all applicable entries.

    b. Any applicable CVE with a Common Vulnerability Scoring System (CVSS) Version 3 severity of medium or higher shall be mitigated prior to vehicle acceptance.

14. Unused capabilities not required for operation or maintenance of a network node or end device shall be removed (e.g., software libraries, communication ports). If removal is not technically feasible it shall be disabled.

    a. Document the capabilities that are not required, including their method of removal or disablement. If any capabilities cannot be removed or disabled, explain the technical reason why and estimate any associated risk as well as how each risk is mitigated.

15. Wireless communications from the onboard network off of the vehicle to wayside services shall be done over a Virtual Private Network (VPN) connection. See NIST SP 800-77. These connections are subject to **approval**.

16. The onboard networks shall be monitored by an Intrusion Detection System (IDS) that is capable of reporting to a wayside Security Information and Event Management (SIEM) system. See NIST SP 800-94.

17. Identify the country (or countries) or origin of all products to be provided under this Contract.

a. Identify the countries where the development, manufacturing, maintenance, and service for the product are provided or will be provided.

b. Submit a list of the proposed products identifying the country of origin (“List” hereinafter).

c. Notify SEPTA of changes to the List no less than 90 days prior to the date that the change will be implemented. Changes will be subject to SEPTA **approval**.

18. Furnish a list of external laptops and devices that may be used to interface with the vehicle, such as during maintenance, testing, or troubleshooting activities.

a. The list shall identify Computer Name, OS and IP address and name or category of intended user. This list shall include laptops and devices specified in Section 19, System Support, as well as any laptops and devices owned by the Contractor and its suppliers.

b. This list shall be maintained starting upon delivery of the first Pilot Car to SEPTA and through the end of the warranty period.

c. The first list shall be supplied to SEPTA 30 days after delivery of the first Pilot Car to SEPTA and then whenever a new laptop or device is added to the list.

d. Audit the list at least every 30 days using the logs specified in TS 17.4.11 #9 to ensure that only listed devices are accessing the car networks.

19. As part of the IEEE Std 1558-2004 documentation required by Section 18, Systems and Software Engineering, describe, at a minimum, the following cybersecurity-related information:

a. The cybersecurity roles and responsibilities applicable to the Contractor and the suppliers.

b. The System Development Life Cycle used to manage subsystem’s software.

c. Detailed Requirements and Design for all software-based security controls referenced in this section.

d. Test Plan and procedures for testing the proper function of all the security controls referenced in TS 17.4.11.

e. Test reports for all the security controls referenced in TS 17.4.11.

20. Prepare and submit a preliminary cybersecurity vulnerability assessment report.

a. Exploits to be considered shall include (but are not necessarily limited to) the following, as appropriate:

- Vandalism
- Eavesdropping
- Device/user impersonation
- Dictionary attacks
- Message modification
- Session hijacking

- Buffer overflow
- Denial of service
- Jamming (physical layer denial of service)
- Virus/worm infection
- Unauthorized software installation
- Unauthorized root/administrator access

b. Considered security measures shall include, but are not limited to the following, as appropriate:

- Restricting physical access to communication and control subsystem components to all but authorized personnel
- Use of Access Control Lists (ACL)
- Use of device and/or user authentication
- Use of encryption
- Use of hardware keys in conjunction with passwords/passphrases
- Access logs
- Intrusion detection/prevention
- Antivirus
- Proper isolation of security-critical subsystem functions from other functions
- Application of secure coding practices
- Use of secure operating systems
- Security logging in alignment with SEPTA's Security Information management (SIM) system

c. The subject preliminary assessment is not required to involve security testing methods such as the independent assessments defined in TS 15, Testing, but rather should be seen as a theoretical analysis that shall use the Contractor's and supplier's past experience in cybersecurity vulnerability analysis along with the understanding of the intended design of the vehicle.

21. Protect the availability, confidentiality and integrity of the data processed and generated by the Streetcar. Implement the cybersecurity practices specified in TS 17.4.11 as per the following Security Controls from NIST SP 800-53 Rev.5:

a. AC-1, AC-2, AC-3, AC-4, AC-5, AC-6, AC-7, AC-14, AC-17, AC-18

b. AU-1, AU-2, AU-3, AU-4, AU-6, AU-7, AU-8, AU-9, AU-11, AU-12

c. SI-4

d. CM-1, CM-2, CM-3, CM-4, CM-8, CM-9, CM-10

e. IA-1, IA-2, IA-3, IA-4, IA-5, IA-7

f. MA-1, MA-3, MA-4

g. PE-1, PE-3

h. PL-8

i. SA-1, SA-3, SA-4, SA-5, SA-8, SA-10

j. SC-1, SC-2, SC-5, SC-7, SC-8, SC-17, SC-19, SC-39

22. The Contractor shall ensure, by integrating specific software security activities into their software development life cycle(s) (e.g., see then NIST white paper Mitigating the Risk of Software Vulnerabilities by Adopting a Secure Software Development Framework (SSDF), April 23, 2020), that security vulnerabilities are identified and removed prior to the delivery of the source code for the independent assessment of software and firmware security.

    a. These activities shall be described in the Contractor's and each supplier's Software Project Management Plan (SPMP), as specified in Section 18, Systems and Software Engineering.

    b. These activities are subject to audit during software Quality Assurance audits, as specified in Section 18, Systems and Software Engineering..

23. Where applicable, all software included within this procurement shall be configured in alignment with the NIST National Checklist Program.

    a. This requirement shall be applied to all software components where NIST National Checklists are applicable. A NIST National Checklist is to be considered applicable if the Software component's name provided to SEPTA is listed in column "Name (version)" of the NIST National Checklist repository (see Item b).

    b. The repository for NIST National Checklist can be found at https://nvd.nist.gov/ncp/repository.

    c. The Contractor and each supplier shall submit:

        - CDRL 17-9, Identification of Subsystem, Associated Software, and Applicable NIST Checklists(s)
        - CDRL 17-10, Completed NIST Checklist(s)

24. Develop, document, and maintain a baseline configuration for all the technology and subsystems loaded onto the car.

    a. The baseline configuration can be developed either manually, or automatically through use of an Instruction Detection System (see TS 17.4.11 #16).

    b. The baseline configuration shall illustrate, at a minimum, the following information:

        - Network map
        - Data flows
        - Communication and protocols (including authentication and encryption)

- Device name
- Device IP address
- Firmware version(s)

25. The Software Configuration Control Plan (CCP) specified in Section 18, Systems and Software Engineering, shall be used for tracking potential security obsolescence in software used in onboard subsystems, Portable Test Units (PTU) and Bench Test Equipment (BTE).

26. Submit information on all communications (e.g., protocols) required between SEPTA's network security zones whether inbound or outbound and identify each.

27. Design subsystems with denial-of-service protection, as defined in NIST SP 800-53 Rev. 5.

28. Propose an authentication method (e.g., password based, IP-based, Certificate based authentication) subject to **approval** for the following types of connections:

    a. Wired connections:

    - Local connection: Temporary connection between external equipment and a car subsystem (e.g., PTU connected to a car subsystem)
    - Network connections between car subsystems and car networks
    - Network connections between external equipment and car networks (e.g., PTU connected through Ethernet Universal Service Port)

    b. Wireless connections (WCN)

29. IP Addresses:

    a. The list of IP addresses assigned to each subsystem on the car is subject to **approval.**

    b. Static IP Address Assignment shall be used to configure the IP scheme of each subsystem connected to the onboard network. When not feasible, the use of Dynamic IP address assignment, such as Dynamic Host Configuration Protocol (DHCP), may be proposed provided that it comes with appropriate security feature (e.g., DHCP snooping) in place.

30. Access Control:

    a. Secure equipment connected to the car network with cabinets, enclosures, and covers that provide a high level of physical security. Use tamper resistant locking hardware. Alternate means to secure equipment that cannot be enclosed may be submitted for **approval.**

    b. Provide means to protect access to the onboard network equipment that hosts one or more Ethernet Ports.

    - Install physical barriers on network equipment that hosts one or more Ethernet Ports.

    c. Ensure that remote access to the onboard subsystems is documented and managed.

    - Document and submit all remote access entry pathways and ensure that they can be enabled or disabled by SEPTA.

d. Design the vehicles to limit access as necessary between specific locations (e.g., security zones, business networks, and demilitarized zones (DMZs)) on the network and submit documentation of the vehicle's configuration as delivered (See CDRL 17-11, Vehicle Baseline Configuration).

- The software shall deny access by default and allow access by specific permissions.
- Provide, for each subsystem relying on a human interface device, user accounts with configurable access and permissions associated with one or more defined user role(s).

31. Verify and submit documentation for the vehicle, attesting that unauthorized logging devices (e.g., key loggers, cameras, and microphones) are not installed on the vehicle following its delivery to SEPTA.

32. Provide means for SEPTA to check the integrity of the software and firmware installed on the car. The version and checksum for every software and firmware loaded onto the vehicle shall be:

    a. Made available on the network

    b. Accessible from the MDS TOD

    c. Available to the Intrusion Detection System (TS 17.4.11 #16)

33. Ensure that the development and Verification & Validation (V&V) activities associated with modifications required on the car (e.g., subsystem software updates) are completed outside the car.

17.4.12 Network Testing

Perform Network Integration Test and penetration testing for each vehicle subsystem and the integrated vehicle network in accordance with Section 15, Testing.

17.4.13 Network Ports

Comply with the following:

1. Provide network ports where specified or where required for connection to the network.

2. Provide the following LED indicators at each network port:

    a. Connection: Green

    b. Activity: Yellow

3. Ports directly attached to equipment shall be M12 as specified in Section 16, Materials and Workmanship. Diagnostic ports intended to be used when vehicle is stationary shall be M12.

17.4.14 Time Synchronization

Comply with the following:

1. The on-vehicle GPS wired to AVL system shall provide the master reference time to synchronize to all non-critical subsystems in Section 13, Vehicle Communication Systems, that require a time synchronization signal via the SNTP protocol.

2. A dedicated master clock signal shall provide time synchronization to propulsion, braking, event recorder, and CBTC equipment in a cybersecure manner that restricts access to propulsion, braking, event recorder and CBTC equipment from other on-vehicle equipment.

3. All wayside monitoring servers shall synchronize the time signal via interface with dedicated ports on SEPTA's master clocks at primary and backup data center.

4. The time system used by all microprocessor equipment, including all event and data recorders, shall be Coordinated Universal Time (UTC). All time displays for the Operator shall be shown in Eastern Standard Time or Eastern Daylight Savings Time, whichever is appropriate for the given date, in 24-hour clock time. The Contractor is responsible for coordinating this requirement with all suppliers.

17.5 Monitoring and Diagnostic System (MDS)

17.5.1 General

Comply with the following:

1. The MDS shall be a physically-distributed, functionally-integrated system that monitors signals and events within the vehicle and within intelligent subsystems on the vehicle and stores the collected subsystem and vehicle data in non-volatile memory located within the selected subsystems and at a central data storage point on the vehicle.

2. The MDS shall be further subdivided into the Central Diagnostic System (CDS) and the Local Diagnostic and Test System (LDTS) resident in each subsystem.

   a. The CDS shall be considered a separate vehicle subsystem and shall be functionality and physically separate from other systems.

   b. A failure of the CDS shall not result in the failure of any other vehicle system.

   c. Each intelligent subsystem shall maintain its own LDTS system with its own fault and diagnostic records.

   d. The Network ICD shall include details on how all faults are collected by the CDS.

3. Each vehicle system LDTS shall include self-diagnostics, status, and fault monitoring, accessible locally via direct PTU connection and via the CDS.

17.5.2 Fault and Event Management

Comply with the following:

1. The following information for all systems on the vehicle shall be captured and retained in non-volatile memory.

    a. Faults: A fault is the activation of a protective function or occurrence of an abnormal condition indicative of current or incipient equipment failure.

    b. Events: An event is a condition that would be expected to occur normally (e.g. actuation of an HMI device, receipt of a command, the application/removal of an input device).

    c. Metadata: With each fault and event (collectively referred to as an "entry") the system shall record both general and entry-specific attributes. The metadata of each entry shall include, but is not limited to:

    - Time and date
    - Values of relevant signals to support diagnostics and troubleshooting
    - Associated subsystem(s)
    - Location in vehicle (if multiple locations exist)
    - Vehicle road number
    - Physical location of vehicle when entry occurred
    - Physical location of vehicle when fault cleared (or blank if fault is still active)

2. Each entry shall have configuration options associated with it.

    a. Configuration Parameter: Characteristic of each entry that is configurable by SEPTA. The configuration parameters shall include, but are not limited to:

    - If the entry is displayed to the Operator
    - The entry severity
    - Associated text displayed on the MDS TOD (s) to the Operator and maintainer including the event title, description, recommended remedial actions, trigger conditions, and fault clear/reset conditions
    - Unique entry code/ID

3. Submit a Fault and Event Management Plan (FEMP) that includes a list of all subsystem faults and events, including associated metadata and initial configuration parameter values.

4. Provide a configuration tool to be used to modify configuration parameters.

5. Create additional entries based on logic equations using available signal values and existing faults and events to provide further capability of isolating faults.

6. Provide diagnostic and failure reporting at levels of detail appropriate for the operating or maintenance function being supported.

7. Operating and maintenance functions that shall be considered include the following:

    a. Operating Failure Identification and Correction:

        - MDS shall communicate information concerning failures affecting vehicle operation to the Operator and other staff, where appropriate, of which they should be aware.
        - MDS shall indicate if the failure is safety-related, affects operating procedures, and is correctable by the Operator or other staff.

    b. Status Assessment:

        - MDS shall communicate sufficient information to enable maintenance personnel to assess operational readiness and suitability for service of each vehicle, before entry into service.

    c. Troubleshooting:

        - MDS shall include detailed data to guide maintenance personnel using troubleshooting procedures to isolate and diagnose faults down to the lowest level possible.
        - This capability shall be built into the vehicle-borne MDS hardware and embedded software to the greatest extent practical; however, use of PTU will be permitted, subject to **approval**.

    d. Intelligent Failure Screening:

        - Each subsystem shall have sufficient diagnostic intelligence to enable it to distinguish between actual subsystem failures and apparent failures caused by failure of another subsystem. For example, auxiliary ac inverter failures causing loss of three-phase power to an HVAC system shall not be reported as an HVAC system failure.
        - Power-up and shut-down sequencing among subsystems shall not generate failure messages.

    e. Repeated instances of the same failure shall be handled such that LDTS memory is not filled with multiple occurrences of the same failure.

8. Energy monitoring data shall be transferred from the propulsion system to the MDS to allow for offload from the vehicle to the wayside and for logging and display onboard the vehicle

17.5.3 Wayside Monitoring and Diagnostic System (WMDS)

Comply with the following:

1. Equip the vehicle MDS with a Wireless Backhaul Radio to transmit MDS and other specified data to SEPTA's facilities.

    a. The MDS shall automatically transmit fault and event data to SEPTA's facilities when a vehicle comes under wayside Wireless Network coverage.

    b. Communication shall be secure and encrypted to prevent unauthorized users from accessing the data or system. Communication shall be done using both secure wireless connectivity

and over a VPN tunnel to the Wayside Monitoring and Diagnostic System (WMDS). All non-VPN traffic should automatically be dropped.

2. Provide software for the storage, interpretation, and assessment of fault data transmitted to vehicle maintenance workstations at SEPTA facilities.

   a. Provide software and hardware compatible with SEPTA's computer systems and wireless backhaul infrastructure to read and display:

      - Vehicles currently under wayside wireless coverage.
      - Real-time vehicle health data when vehicles are under wayside wireless coverage.
      - View historical fault and event data that was previously transferred to the WMDS.

   b. It shall collect and analyze the data from the MDS and other specified systems.

   c. Wayside data shall be stored in a relational database (e.g. MSSQL) to allow for efficient management of large datasets and analysis.

      - The relational database shall support ACID (Atomicity, Consistency, Isolation, Durability) transaction properties.
      - Storing of wayside data in individual files is prohibited.
      - The database schema shall be provided along with associated documentation on how the schema is used.

   d. All wayside applications shall be web-based such that they can be accessed from any modern HTML5, CSS3, and JavaScript compatible web browser on any computer having network access and authorized access.

      - Wayside application user account management is subject to the vehicle requirements specified in this Section.
      - Any application licenses provided shall allow for unlimited simultaneous access, users, and open sessions.
      - The permissible quantity of simultaneous open sessions shall be limited only by the WMDS server capacity, which shall be designed to be expandable from a base design criterion of 20 simultaneous web-based sessions.

   e. All wayside application functions that are capable of being performed using the primary web-based interface (e.g. file upload, fault and event log query) shall also be possible via an Application Programming Interface (API).

      - The API shall allow for authorized queries of all wayside datasets (e.g. searching for passenger boarding counts for a specified date and vehicle range).
      - Submit full documentation of all API functions, expected inputs and expected outputs including variables and structure (e.g. ASCII-encoded JSON).
      - All API interactions shall be validated and allow only authorized actions to be performed.

3. Provide an automatic scheduler such that uploads to the vehicle and downloads from the vehicle can be scheduled to happen at a certain time for a specific vehicle or set of vehicles.

    a. If the scheduled vehicle is not in communication with the WMDS when an event is scheduled, the update shall happen automatically when the scheduled vehicle is in communication with the WMDS.

    b. The WMDS shall give feedback of the transfer progress to all applicable vehicles to allow an administrator to verify that all scheduled transfers have completed.

4. SEPTA approval required for automatic scheduler functionality and method.

17.5.3.1 Fleet Management WMDS Functions

The Fleet Management Wayside Application Software shall include the following functions:

1. Maintain the history of all Software Configuration Items (SCIs) and status changes, making it possible to determine which versions currently reside in which equipment, on which vehicles, and which versions were used in the past.

2. Automatically read the current software configuration of the entire fleet on a scheduled basis.

3. Maintain the nominal configuration for each SCI on a vehicle-by-vehicle and an item-by-item basis:

    a. SCI update capability for the fleet:

        - The update capability shall function for each system on the vehicle.
        - The WMDS shall provide an interface to upload a new version of an SCI and have it uploaded to specified vehicles in the fleet.
            - The vehicle shall accept the update package from the WMDS and store it in non-volatile memory.
        - The onboard storage shall have capacity to store an update for each SCI on the vehicle simultaneously.
            - Once an SCI update package is installed, it may be deleted from memory.
        - The Maintenance Screen shall provide a list of pending SCI update packages per the Maintenance Screen section, below.
            - It shall be possible to verify the checksum of each SCI in memory on the vehicle.
            - It shall be possible to calculate and verify the checksum of each SCI installed on the vehicle.

4. User account management as required above for Network Cybersecurity.

5. Fault and Event log download.

6. Communication system data updates per Section 13, Vehicle Communication Systems.

17.5.4 MDS Train Operator Display(s) (TOD)

17.5.4.1 General

Comply with the following:

1. There shall be one or more MDS TOD screens in each cab.
    a. If two or more MDS TOD screens are provided, the MDS TOD screens shall be fully redundant so that any MDS TOD screen can serve all TOD functions and serve as hot standbys for each other in case there is a failure of MDS TOD supporting control, data, and power circuits
    b. The loss of a single MDS TOD screen shall not prevent safe operation of the vehicle.
2. The MDS TOD is the primary source of information for the Operator while the vehicle is in motion or at a stop.
3. MDS TOD screens shall be in accordance with Section 5, Operator's Cab Controls, and shall comply with the following:
    a. Configuration: Flush mounted.
    b. Size: Minimum diagonal measurement of 10 inches in respect to a 4:3 aspect ratio.
    c. Resolution: Minimum of 1024 x 768 pixels.
    d. Type: Button controlled. Shall respond to control buttons on perimeter of screen. A touch screen shall not be used without **approval.**
    e. Brightness and contrast:
        - Adjustable.
        - Selectable between automatic and manual brightness adjustment by the Operator.
        - Screens shall be visible in all lighting conditions, shrouded if necessary.
        - Minimum brightness shall be visible (i.e. not "black").
4. TOD screens shall be arranged in a hierarchal manner with five top-level HMI screens:
    a. Operator Screen
    b. Status Screen
    c. Fault Screen
    d. Maintenance Screen
    e. APIS Screen
5. Each MDS TOD screen may use one or more subscreens to provide additional relevant information.
    a. Subscreens shall not be used unless necessary to display the required information.

b. The hierarchal screens shall be arranged in a consistent interface to facilitate moving up and down the hierarchy.

6. All screens shall use a common set of controls and design elements.

    a. For all systems in all vehicles in the train, there shall be a summary color indication for the most severe active fault in each system that can be further expanded upon using the Fault Screen (e.g., green/no color = no fault; yellow = one or more minor active faults; red = one or more major active faults; blue = cut out) . Color coding and design elements shall require **approval**.

7. Maintenance functions accessible through the MDS TOD shall be password-protected, subject to the user account management requirements of the Network Cybersecurity section, above.

8. Date and time shall be visible on all screens in the format MMM-DD-YYYY HH:MM:SS (e.g., Jan-01-2019 13:00:00), subject to the requirements in the Time and Date Processing section, below.

9. The highest severity faults shall be displayed to the Operator on the primary MDS TOD (e.g. as a pop-up alert) and sound an audible alert until the Operator acknowledges the fault.

    a. This attribute of a fault shall be configurable.

    b. A de-bounce scheme shall be used to prevent the display of repeat faults in a short period of time.

    c. Provide a way for the Operator to acknowledge all active faults without obscuring content necessary for operation.

10. TOD screens in non-active cabs shall be in an energy saving mode with the screens off. Screens should also have a control to re-activate manually for testing purposes for maintainers in non-active cab.

11. The number of the vehicle in which the physical MDS TOD is installed shall be visible on every screen

12. See Section 5, Operator’s Cab Controls, for location of the MDS TOD(s) in the cab and additional TOD requirements.

13. Contractor shall participate in a series of working sessions with SEPTA to present human factors and ergonomic display of HMI content.

17.5.4.2 Operator Screen (Displayed Content)

Comply with the following:

1. The Operator Screen shall be configured to present summary operating status information to the Operator without requiring scrolling.

2. The Operator Screen shall be the default primary screen available upon power-up.

3. The Operator Screen shall display a graphic of all the vehicles in the train, including:
    a. The location and orientation of each vehicle in the train.
    b. Each vehicle's number.
    c. The active cab.
    d. The selected direction of movement.
    e. A graphic display of door status for each door in each vehicle.
4. The Operator Screen shall provide the following:
    a. Speedometer.
        - Vehicle speed in miles per hour (mph).
        - Current speed limit.
        - Brake intervention threshold speed.
    b. Stop requested.
    c. Bridge plate requested.
    d. PEI activated.
    e. Bypass active indications.
    f. Cutout active indications.
    g. OCS voltage.
    h. Battery voltage.
    i. Tractive effort and braking effort
    j. Graphical Indication of which doors are open.
    k. All Doors Closed and Locked signal: Green = TRUE, Yellow = FALSE, Red = Fault.
    l. Specific system summary information to be determined during Preliminary Design Review (PDR).
    m. Special vehicle function buttons to be determined during PDR.
    n. Other indications specified in Section 5, Operator's Cab Controls.

17.5.4.3 Status Screen

Comply with the following:

1. The Status Screen shall graphically show the status of all the systems on the vehicle.
2. The Status Screen shall graphically show the health status of each subsystem for each vehicle in the train.

3. The Status Screen shall provide the following, which may be hosted in subscreens:

    a. A list of all bypasses and their states.

    b. A list of all cutouts and their states.

    c. Specific system statuses and values (e.g., tractive effort (kN), motor current (A), passenger space temperature (°F), APS output contactor state) to be determined at PDR.

    d. A legend describing all symbols and colors used in the Status Screen.

    e. A graphical representation of the data network communication status of each physical link and end device.

17.5.4.4 Fault Screen

Comply with the following:

1. The Fault Screen shall show a tabular list of all currently active and unacknowledged faults since vehicle power-up.

    a. Only faults, alarms, or notifications configured to be displayed to the Operator shall be displayed.

2. Faults shall be displayed with:

    a. A descriptive name.

    b. Associated metadata as specified in the Fault and Event Management section, above.

3. The Operator shall be able to filter the fault table by vehicle number and subsystem.

4. For each fault, there shall be a subscreen that provides the following information regarding the selected fault:

    a. Fault name.

    b. Physical location of vehicle when fault occurred (e.g. 200 feet after Station X, or near Cross-Street Y).

    c. The quantity of occurrences of the fault since vehicle power-up.

    d. Detailed description of the fault including the triggering conditions that caused the fault.

    e. What actions the Operator should take to recover from the fault.

17.5.4.5 Maintenance Screen

Comply with the following:

1. The Maintenance Screen shall be configured to allow maintainers to perform vehicle maintenance procedures, set maintenance dependent parameters, initiate installation of SCI updates sent from the WMDS, and view fault history information.

2. Access to the Maintenance Screen shall be password-protected, subject to the user account management requirements of the Network Cybersecurity section, above.

3. The Maintenance Screen shall show a tabular list of all active and historical faults and events stored by the CDS.

   a. The maintainer shall be able to filter the fault and event table by:

      - Fault status (whether the fault is currently active or not)
      - The vehicle subsystem
      - The vehicle Road Number
      - A provided date and time range of fault or event occurrence
      - A provided range of physical locations of the vehicle when the fault or event occurred (e.g. between Station X and Station Y)
      - The fault or event severity

   b. The maintainer shall be able to sort the fault and event table by all displayed columns.

   c. For each fault, there shall be a subscreen that provides the following regarding the selected fault:

      - The same information displayed on the Fault Screen
      - Conditions required for a fault reset
      - Conditions required for a lockout reset
      - List of possible causes

4. The Maintenance Screen shall graphically show the health status of each subsystem for each vehicle in the train.

   a. Each subsystem shall be able to be further subdivided into its major components.

5. The Maintenance Screen shall be able to perform the following:

   a. Display all current SCI versions installed on the train.

   b. Display SCI update packages uploaded to the vehicle that are pending installation:

      - Each pending SCI package shall display the version of the currently installed SCI, the version of the pending SCI update, the date the SCI update was received from the WMDS, and the checksum of the pending SCI update
      - The Maintenance Screen shall allow the maintainer to initiate the installation of each SCI update and display the installation progress
      - Prior to the installation of the selected SCI, a confirmation dialog shall be presented that indicates which SCI is about to be updated

   c. Initiate all subsystem self-tests on the train and display the results.

d. Display the status of all Remote I/O module values:
   - Each signal shall include a label
   - Digital signals shall indicate if they are active high or active low
   - Analog signals shall display interpreted data in engineering units and not raw input data

e. Display the status of all signals used for train control:
   - Each signal shall include a label
   - Digital signals shall indicate if they are active high or active low
   - Analog signals shall display interpreted data in engineering units and not raw input data
   - Signals shall be able to be filtered by subsystem

6. Manual entry for the wheel diameters for non-CBTC functions shall be made on the Maintenance Screen:

   a. Reading of wheel diameter shall not require additional password in addition to access of Maintenance Screen.

   b. Changing wheel diameter entry shall require an additional password separate from access to the Maintenance Screen.

   c. The wheel diameter entry function shall not accept out-of-range values. If the braking or propulsion systems detect wheel size mismatch it will be forwarded for display to the MDS.

7. Specific additional maintenance functions will be determined during PDR.

17.5.5 Global Positioning System (GPS) Receiver

Provide a Wide Area Augmentation System (WAAS)-enabled GPS receiver wired to the MDS system. System shall forward GPS information to any other onboard network subsystem that calls for GPS information in Section 13.

1. The GPS shall furnish the primary vehicle time, which shall be passed on to all relevant vehicle control systems via the vehicle network.

2. Provide satellite prediction and recent ephemeris data features for quicker location determination when the GPS is powered on.

3. Provide an interface at the VNC and MDS to GPS data, allowing access by other vehicle systems to vehicle location data and GPS time signals via Ethernet connection. Include appropriate access methods and software techniques for other systems to access such data.

4. The GPS shall remain powered during vehicle layover periods. See Section 5, Operator’s Cab Controls, and Section 9, Electrical Equipment, for vehicle layover.

5. Mount the GPS antenna on the roof, or other location, optimized for satellite access. Coordinate the antenna location with other vehicle antennas to avoid interference.

17.5.6 Time and Date Processing

Comply with the following:

1. All systems provided, whether acting separately or in combination, shall properly process all times and dates within the required span of years from 2000 to 2099 inclusive. This includes all onboard and wayside software as well as all BTE, PTU, Development Systems, Operating Systems, and workstations.
2. Time information shall be transmitted, stored, and otherwise used by all onboard and wayside systems as a pair formed of UTC date and time in seconds with dynamic local time offset, in a standard format and representation that is immune to overflow errors for the life of the vehicle.
3. All vehicle-borne and wayside systems shall display times as local time to the user.
4. All onboard systems shall synchronize to the Master Clock and allow for centralized automatic adjustment of time zone and daylight savings time (DST).
    a. DST adjustment logic shall be updateable if the current defined logic becomes obsolete.
5. All wayside systems shall synchronize time and date to an accepted reference.
6. Analysis and test shall establish that all systems process times and dates correctly.
7. Because setting time and date is required as part of normal vehicle operations and is required for system validation testing, the design shall allow for setting of the time for the whole system or for any part of the system, forward or back, to any time in the required span of years from 2000 to 2099, without incorrect operation or loss of data.

17.5.7 Wayside Servers

Coordinate with SEPTA'S IT department for specific wayside server requirements. Submit wayside server details for **approval.** The following requirements are provided as guidance based on the current understanding of SEPTA's IT requirements but do not relieve the need for **approval**:

1. Virtualization:
    a. All servers are deployed as virtual machines using VMware vSphere hypervisor.
    b. No hardware servers will be deployed
    c. All server hardware is managed by SEPTA IT.
2. Operating Systems:
    a. Windows servers must use Windows Server 2016 or later.
    b. Linux servers must use Ubuntu 20.04 LTS or later LTS release (only LTS releases are deployed).
    c. Server operating systems are managed by SEPTA IT.

3. CPU: Up to 96 cores running at 2.4 Ghz can be provided per server.

4. Memory: Up to 512 GB of RAM can be provided per server.

5. Storage:

   a. The following physical storage types are available:

      - Spinning disk
      - SSD

6. Database: Microsoft SQL Server 2014 or later is the preferred database platform

7. Management

   a. All servers will be joined to SEPTA's domain

   b. All Windows servers will have SEPTA's Group Policy Objects applied.

   c. Software updates for operating systems and COTS software will be automatically performed by SEPTA in accordance with SEPTA's update schedule.

8. Security:

   a. All servers will have SEPTA's endpoint protection (EDR, antivirus, antimalware, etc.) software installed.

   b. All server admin work will only be performed using Privileged access Workstations that are physically separate from normal workstations.

9. Remote Access

   a. Remote access, if necessary, will be supplied through SEPTA's privileged remote access system.

   b. No other forms of remote access will be allowed.

10. Network:

    a. The TCP/UDP ports and application protocols used by the application must be identified.

    b. Estimated bandwidth usage and throughput requirements must be provided.

11. Encryption

    a. Traffic must be encrypted in transit with TLS.

       - TLS minimum version is 1.2.

12. Data access/interchange

a. All interfaces with other SEPTA systems used to exchange data must be identified and described.

b. All communications with other SEPTA systems must be encrypted.

c. TCP/UDP ports and application protocols for these data transfers must be identified.

17.5.8 Wayside Workstations

Coordinate with SEPTA's IT department for specific wayside workstation requirements. Submit wayside workstation details for **approval.** The requirements in TS 17.5.7 can be referred to for guidance but do not relieve the need for **approval**.

17.6 Wayside IT Infrastructure

17.6.1 SEPTA-Provided Network Infrastructure

Coordinate with SEPTA's IT department for specifics of SEPTA-Provided Network Infrastructure. Use the information provided in TS 17.5.7 as a baseline.

a.

17.6.2 Contractor-Provided Network Infrastructure

Coordinate with SEPTA's IT department for specific requirements. If SEPTA determines it necessary, Contractor shall provide the following:

1. Firewalls and VPN gateways
2. Data diodes
3. Core network switches

17.6.3 Contractor-Provided Servers

Contractor shall provide the following:

1. MDS servers
   a. Fault logging servers
   b. Software updates servers (Option)
2. Network services servers:
   a. 802.1x authentication server
   b. Active Directory (Windows)/LDAP (Linux) servers
   c. WSUS server (Windows Updates)

d. Antivirus server

e. Backup server

17.7 Contract Deliverables Requirements List (CDRL)

17-1 Network Interface Control Document (ICD)
17-2 Vehicle Control System Design Package
17-3 Vehicle Data Network Design Package
17-4 Monitoring and Diagnostic System Design Package
17-5 Fault and Event Management Plan
17-6 List of Proposed Products and Countries
17-7 List of External Information Systems
17-8 Vehicle Communication and Control System Vulnerability Preliminary Assessment
17-9 Identification of Subsystem, Associated Software, and Applicable NIST Checklist(s)
17-10 Completed NIST Checklist(s)
17-11 Vehicle Baseline Configuration
17-12 Unauthorized Logging Device Removal Statement

17.8 CDRL Detail

Submit the following in accordance with Section 19, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

17-1 Network Interface Control Document (ICD):

1. The Network ICD shall document all communications over the data networks and include:

    a. Signal name.
    b. Signal description.
    c. Brief explanation of signal function.
    d. System(s) concerned.
    e. Signal sender.
    f. Signal receiver(s).
    g. VLAN(s) and network(s) used (data path).
    h. Data format.
    i. Data port.
    j. Data protocol(s) (e.g., HTTPS, TRDP, SFTP, FTPS, SNTP).
    k. Frequency and duration of transmission.
    l. Type of transmission service (e.g., broadcast, multicast, TCP, UDP).

17-2 Vehicle Control System Design Package:

1. Vehicle control system circuit drawings and diagrams including the following:

    a. Hardwired circuit drawings
    b. Functional descriptions

2. Sneak circuit and single point failure analysis, as specified in Section 2, Design and Performance Criteria, that covers emergency loads, interlocks and safety critical functions.

17-3 Vehicle Data Network Design Package:

1. Description of vehicle data network, network protocols, and transmission methodology.

2. Calculations of the variations in transmission time, as related to real-time control requirements, with a statement of acceptability by the propulsion and the brake supplier.

3. Detailed calculations of peak and average data traffic levels and calculations of network delays.

    a. Network delay calculations: Include expected average delays and distribution of delay times.
    b. Peak and average traffic levels for transmission media, as recommended by protocol Supplier.

4. Describe process whereby problems with networks will be detected, reported, and repaired.

5. Vulnerability assessment of hacking via wireless access or vehicle ports.

17-4 Monitoring and Diagnostic System Design Package:

1. Mechanical specifications of the system

2. Mechanical assembly drawings with weights, dimensions, and parts lists

3. Electrical schematic drawings for system interconnections

4. Electrical schematic drawings for each device and assembly

5. Installation drawings

6. Layout of each screen with descriptions of each screen element and its use and operation

7. MDS TOD:

    a. Monitor details:

        - Type
        - Size
        - Resolution
        - Ambient conditions
        - Operating voltage

- Protective cover
- Isolating power supply

b. Sample screen displays
c. Description of navigation
d. Listing of available displayed data for each system

8. Portable Test Unit (PTU):

a. Laptop specifications
b. Portable Test Unit Software

17-5 Fault and Event Management Plan

17-6 List of Proposed Products and Countries

1. Submit the List in MS Excel format and in PDF format (signed copy from the Contractor).

2. The hardware portion of the List shall be based off the Illustrated Parts Catalog specified by Section 19, System Support.

3. The list shall contain all software installed on the vehicle.

17-7 List of External Information Systems:

1. Submit the list in MS Excel format and in PDF format (signed copy from the Contractor).

2. Include in the list the information specified in Section 17.4.11 #18a.

3. Submit the first list 30 days after delivery of the first Pilot Car to SEPTA and then whenever a new laptop or device is added to the list.

17-8 Vehicle Communication and Control System Vulnerability Preliminary Assessment:

1. Submit the report in MS Word format and in PDF format (signed copy from the Contractor).

2. The preliminary cybersecurity vulnerability assessment report shall identify the following:

a. All potential subsystem vulnerabilities
b. All exploitation techniques from the MITRE Adversarial Tactics, Techniques, and Common Knowledge (ATT&CK) framework applicable to this project
c. Countermeasures considered for mitigating identified vulnerabilities
d. The format of the Vulnerability Preliminary Assessment shall be similar to that of a Hazard Analysis, consistent with the format specified in Section 2, Design and Performance Criteria, but independent of the Hazard Analysis specified in Section 2. Submit a representative sample of the proposed assessment format for Approval prior to submitting the assessment itself.
e. Submit the report at PDR.

17-9 Identification of Subsystem, Associated Software, and Applicable NIST Checklist(s):

1. Submit the list in MS Excel format.

2. The list shall include one column for each of the following:

    a. Vendor Name
    b. Subsystem Name
    c. Subsystem Software Name and Version
    d. Corresponding Security NIST Checklist Name
    e. Security NIST Checklist Implementation Status (Open/Closed)

3. Submit the list at PDR and at FDR.

17-10 Completed NIST Checklist(s):

1. Submit the completed version of the list specified under CDRL 17-9.

2. Submit the list in MS Excel format and in PDF signed by the applicable vendor(s) and the Contractor.

3. Submit the list at FDR.

17-11 Vehicle Baseline Configuration

1. Submit the Vehicle Baseline Configuration in MS Excel format, with two tabs, as follows:

    a. “Network Map and Data Flow” tab shall be a diagram illustrating the network and connected devices. Include the following in the diagram:

        - Vehicle Network
            - Switches (L2)
            - Routers (L3)
            - End Devices
            - VLANs and subnets
            - Trunk Ports
        - Interface with Wayside Equipment
        - Network Security Zones
        - Interface with SEPTA corporate Network

    b. “Communication” tab shall be a table documenting the following information:

        - Source System Name
        - Destination System Name
        - Source IP Address
        - Destination IP Address
        - Protocol Name
        - Protocol Priority
        - Unicast/Multicast
        - Port Number

2. Submit the list at PDR, FDR, and upon delivery of the first Pilot vehicle to SEPTA.

17-12 Unauthorized Logging Device Removal Statement:

1. Submit the statement in the form of an attestation stating that the vehicle does not host any unauthorized logging device at the time of its delivery to SEPTA.
2. Submit the confirmation in a PDF signed by the Contractor.
3. Submit the confirmation upon delivery of the corresponding vehicle to SEPTA.

17.9 Referenced Standards

The following standards are referenced in this Section:

EN 50155	Railway applications - Rolling stock - Electronic equipment
IEC 61375-1	Electronic railway equipment - Train communication network (TCN) - Part 1: General architecture
IEC 61375-2-3	Electronic railway equipment - Train communication network (TCN) - Part 2-3: TCN communication profile
IEC 61375-2-5	Electronic railway equipment – Train communication network (TCN) – Part 2-5: Ethernet Train Backbone (ETB)
IEC 61375-2-6	Electronic railway equipment – Train communication network (TCN) – Part 2-6: On-board to ground communication
IEC 61375-3-4	Electronic railway equipment - Train communication network (TCN) - Part 3-4: Ethernet Consist Network (ECN)
IEC 62443	Security for industrial automation and control systems
IEEE Std 802.1D	Standard for Local and metropolitan area networks: Media Access Control (MAC) Bridges
IEEE Std 802.1Q	Standard for Local and metropolitan area networks--Bridges and Bridged Networks
IEEE Std 1475	Standard for the Functioning of Interfaces Among Propulsion, Friction Brake, and Train-Borne Master Control on Rail Rapid Transit Vehicles
IEEE Std 1558-2004	Standard for Software Documentation for Rail Equipment and Systems
NIST SP 800-53	Security and Privacy Controls for Federal Information Systems and Organizations
NIST SP 800-77	Guide to IPsec VPNs
NIST SP 800-82	Guide to Industrial Control Systems (ICS) Security
NIST SP 800-92	Guide to Computer Security Log Management, September 2006

NIST SP 800-94	Guide to Intrusion Detection and Prevention Systems (IDPS)
NIST SP 800-115	Technical Guide to Information Security Testing and Assessment
NIST SP 800-160	Systems Security Engineering: Considerations for a Multidisciplinary Approach in the Engineering of Trustworthy Secure Systems
RFC 5340	OSPF for IPv6
RFC 5424	The Syslog Protocol

White Paper Mitigating the Risk of Software Vulnerabilities by Adopting a Secure Software Development Framework (SSDF), April 23, 2020

END OF SECTION

Table of Contents

Table of Tables

18.1 Description

18.1.1 General

All systems, and all computer hardware and software to be provided under this Contract, are subject to the requirements provided in this Section, whether resident within a microprocessor-controlled intelligent subsystem, provided as part of test or interface equipment, provided for the purpose of post-download data analysis and processing, or incorporated within training technology and manuals, and non-generic Bench Test Equipment (BTE).

18.1.2 Contractor and Supplier Qualification

Comply with the following:

1. The Contractor, as the systems and software integrator, shall implement disciplined systems engineering, integration, and supplier management processes. To demonstrate its capability, the Contractor shall submit either:

   a. The results of a current, independent, Standard Capability Maturity Model Integration (CMMI) Appraisal Method for Process Improvement (SCAMPI) Class A Appraisal. The appraisal shall use the Capability Maturity Model Integration for Development (CMMI-DEV), v1.3as defined by ISACA. The appraisal reference model scope, at a minimum, shall be the following Target Profile: Capability Level 2 in the following Process Areas:

      i. Configuration Management
      ii. Measurement and Analysis
      iii. Process and Product Quality Assurance
      iv. Project Monitoring and Control
      v. Project Planning
      vi. Requirements Management
      vii. Supplier Agreement Management
      viii. Product Integration
      ix. Requirements Development
      x. Technical Solution
      xi. Verification
      xii. Validation

OR

   b. The results of a current, independent, CMMI v2.0 Benchmark Appraisal. The appraisal shall use the Capability Maturity Model Integration V2.0, as defined by ISACA. The appraisal reference model scope, at a minimum, shall be the following Target Profile: Capability Level 2 in the following Practice Areas:

      i. Configuration Management

ii. Managing Performance and Measurement

iii. Process Quality Assurance

iv. Estimating

v. Planning

vi. Monitor and Control

vii. Requirements Development and Management

viii. Supplier Agreement Management

ix. Technical Solution

x. Product Integration

xi. Peer Reviews

xii. Verification and Validation

xiii. Governance

xiv. Implementation Infrastructure

2. Suppliers and their sub-suppliers shall implement disciplined software engineering processes.

   a. Sub-supplier: Anyone other than the Contractor or its direct suppliers who provides software on this Contract. Regardless of who provides software, the Contractor shall ultimately be responsible for all software provided under this Contract.

   b. To demonstrate its capability, the Contractor shall submit, for each supplier and sub-supplier providing software, either:

      i. The results of a current, independent, Standard CMMI Appraisal Method for Process Improvement (SCAMPI) Class A Appraisal for the aforementioned Target Profile (Section 18.1.2, Item 1.a).

OR

      ii. The results of a current, independent, CMMI V2.0 Benchmark Appraisal for the aforementioned Target Profile (Section 18.1.2, Item 1.b), as defined by the ISACA CMMI Method Definition Document V2.0.

3. If the results of a current, independent Appraisal (SCAMPI Class A or Benchmark Appraisal as defined above) that documents a rating of Capability Level 2 in the Target Profile, are unavailable for the Contractor, supplier, or any entity providing software, submit:

   a. The results of a current, independent CMMI V2.0 Evaluation Appraisal and a Project-Specific Remedial Action Plan. The appraisal Model scope, at a minimum, shall be the following Target Profile: Capability Level 2 in the following Practice Areas:

      i. Configuration Management

      ii. Managing Performance and Measurement

      iii. Process Quality Assurance

iv. Estimating

v. Planning

vi. Monitor and Control

vii. Requirements Development and Management

viii. Supplier Agreement Management

ix. Technical Solution

x. Product Integration

xi. Peer Reviews

xii. Verification and Validation

xiii. Governance

xiv. Implementation Infrastructure

4. The Contractor shall monitor its suppliers and sub-suppliers for their progress in effectively implementing their respective Remedial Action Plan.

5. To be considered independent, the Lead Appraiser shall not be affiliated with the Contractor or the suppliers/sub-suppliers and shall not have been involved with their improvement activities. To be considered current, the Appraisal Disclosure Statement (ADS) shall be dated no more than two years prior to Contract Award.

6. The appraisal organizational scope shall cover the parts of the organization that are responsible for the entire range of activities performed by the Contractor or supplier/sub-supplier in the domains of systems engineering, product integration, supplier management, software engineering, and microprocessor-based systems.

7. The independent appraisals shall include the use of a I Lead Appraiser certified by ISACA.

8. The suppliers' and sub-suppliers' (And Contractor's if applicable) software engineering process, including proprietary or internal procedures, and software work products including source code, shall be available for inspection and review by SEPTA during any regularly scheduled site visit, such as Software Quality Assurance/Quality Assurance (SQA/QA) audits, Design Reviews, FAIs, and routine hardware inspections.

18.1.3 Systems Engineering

The Contractor and each supplier shall implement a disciplined systems engineering process that culminates in a set of requirements that includes, but is not limited to, performance, functional, and non-functional requirements (see INCOSE TP-2003-002-03.2.2 for guidance).

1. This set shall either be included in the System Functional Requirements Specification (SFRS) or referenced from within the SFRS. Additionally, the SFRS shall contain a System Requirements Allocation Matrix (SRAM) and, if applicable, a Software Configuration Summary Table (SCIST) and a PDST.

2. The System Requirements shall be:

   a. Necessary

   b. Implementation Independent

   c. Clear and Concise

   d. Complete

   e. Consistent

   f. Achievable

   g. Traceable

   h. Verifiable

3. System Functional Requirements Specification:

   a. Composition:

      i. Overview: Clearly describe and graphically depict the system hardware components, including microprocessors and programmable devices, if applicable, Software Configuration Items (SCIs), if applicable, and the interfaces between these components. The overview shall also be incorporated into the Functional Description (FD).

      ii. Requirements: A requirements set, including functional, performance, and non-functional (e.g., safety) requirements, at each level (i.e., train, and subsystem), shall be developed and maintained. A requirements management tool may be used to accomplish this, in which case the tool database shall be referenced from within this section.

      iii. SRAM:

         - An SRAM shall be generated at the train level and system level. The SRAMs shall also be included in the FDs.
         - Train Level: The origin of all train-level requirements (e.g., Specification section, standard product, typical implementation, internal, etc.) shall be specified. Each requirement shall be forward-traceable to system(s).
         - System Level: The origin of all system-level requirements shall be specified. Each requirement shall be forward-traceable to a hardware component or SCI.

      iv. For systems that contain software or programmable devices:

         - SCIST: The SCIST shall include the following information for each SCI and also be incorporated into the System Functional Description (SFD):
            - SCI Part Number
            - SCI Name
            - Escrow (Yes or No)
            - Software Application Type (Onboard, Wayside, PTU, BTE, or Workstation)

- System
- Application (SCI name)
- Software Manufacturer Name (Origin)
- Software Manufacturer Part Number
- Non-Commercially Available or Commercial Off-the-Shelf (COTS)
- System Requirement Allocation Table Reference
- Software Requirements Specifications (SRS) Reference
- Software Design Description (SDD) Reference
- Unit/Assembly System Name and Part Number
- Processor/Logic Device - System Supplier Part Number
- Memory Device - System Supplier Part Number
- Processor/Logic Device - OEM Name and Part Number
- Memory Device - OEM Name and Part Number
- Classification Category (A or B)
- How Programmed
- Development Environment
- Editor
- Compiler
- Assembler
- Linker
- Libraries
- Additional Programming Tools.

- PDST: The PDST shall include the following information for each device and also be incorporated into the FD:
  - Device/Component Name
  - SCI Part Number
  - Device Purpose
  - Basic Architecture (Microprocessor Type, CPLD, FPGA, SPLD, ASIC)
  - Programmability (One-Time, In-System, Re-Programmable)
  - Programming Method (JTAG, Portable Test Unit (PTU), or Device Programmer)
  - Manufacturer
  - Manufacturer Part Number
  - Supplier Part Number

- Printed Circuit Board Part Number

4. Interface Control Document (ICD) for each system-to-system interface at the vehicle level (e.g., friction brakes to propulsion)/multisystem (e.g., network). The format shall comply with IEEE Std 1558-2004.

18.2 Design Reviews

18.2.1 General

Conduct design reviews and provide design documentation as required by Section 20, Program Control and Quality Assurance, and at other times as appropriate, as the design of the vehicle progresses.

1. Provide comprehensive documentation 30 calendar days in advance of the design reviews for each system to enable SEPTA to be an active participant in the design review process.

2. All documentation shall be prepared in coordination with a native-English-speaking technical writer so that the information is presented in US English, clearly and concisely written.

3. The Contractor and its suppliers shall be responsible for documenting the results of meeting discussions and actions to be taken (i.e., action items) in real time. The documentation shall be reviewed prior to the conclusion of the meeting by all in attendance to verify its accuracy and comprehensiveness.

   a. Action items shall be assigned to an organization for follow-up resolution within 30 days unless another time frame is agreed upon during the meeting.

   b. The Contractor and its suppliers shall develop and maintain a consolidated action items list by system to facilitate tracking and closeout of issues and shall furnish it in advance of design reviews and other interim working group meetings.

18.2.2 Document Delivery Schedule

TABLE 18-1, DOCUMENT DELIVERY SCHEDULE			
Milestone	**CDRL**	**Contractor**	**Suppliers**
Prior to PDR	SCAMPI Class A Appraisal Disclosure Statement, and Final Findings Presentation (if CMMI rating of Capability Level 2 in Target Profile)	X	X
	CMMI V2.0 Benchmark Appraisal Disclosure Statement, Final Findings Report, and Performance Report	X	X
	Project-specific Remedial Action Plan (if no CMMI rating)	X	X
	CMMI V2.0 Evaluation Appraisal Results: Organizational Unit Practice Characterizations and Final Findings Presentation	X	X
Preliminary Design Review (PDR)	Standard Software Documentation Methodology	X	
	Software Project Management Plan (SPMP)	X	X
	Software Quality Assurance Plan (SQAP)	X	X
	Cab and Train Functional Description	X	
	Interface Control Document(s) (vehicle-level)	X	
	System Functional Requirements Specification		X
	Software Project Management Plan (SPMP)	X	X
	Software Quality Assurance Plans (SQAP)	X	X
	Software Configuration Management Plan (SCMP)	X	X
	Software Verification and Validation Plan (SVVP)	X	X
	Software Test Plan (STP)		X
	Software Requirements Specifications (SRS)		X
	Software Design Descriptions (SDD) - Preliminary		X
	Database Design Description (DBDD) - Preliminary		X
	Software Requirements Traceability Matrix (SRTM) – SFRS to SRS columns complete		X
	Software User Manuel (SUM) - Preliminary		X
In-process Design Review (IPDR) if required by Engineer	Update of PDR documents	X	X
	Software Verification and Validation Report - Interim (results of software V&V activities performed thus far)		X
Final Design Review (FDR)	Complete versions of all PDR documents	X	X
	Software Test Procedure(s) (STPr)		X
	System Functional Description		X
	Software Workstation Build Procedures	X	
	Software Version Description (SVD)		X

TABLE 18-1, DOCUMENT DELIVERY SCHEDULE			
Milestone	**CDRL**	**Contractor**	**Suppliers**
Prior to Type Testing or FAI whichever occurs first	Software Test Report(s) (STR)	X	X
	Software Verification and Validation Report (SVVR) - Final	X	X
Quarterly	Project-specific Remedial Action Plan Quarterly Report (if no CMMI rating)	X	X
Software Delivery	As-built versions of all FDR and System Qualification Testing documents.	X	X
Submit list of Source Code to Escrow During PDR Conduct Escrow verification test and perform Escrow after software is finalized during the warranty period	Source Code to Escrow		X
Prior to the acceptance of the first vehicle	Software Workstation		X

18.2.3 Functional Description

18.2.3.1 General

Comply with the following:

1. Scope and Purpose:

   a. FDs shall include the SFDs, and the Cab and Train Functional Description (CTFD).

   b. Each FD shall serve initially as a design review document and shall be developed into a permanent reference as the project progresses. Each FD shall be updated for each relevant design review and, thereafter, promptly whenever needed through the end of the warranty period.

   c. Each FD's scope, style, and level of detail shall be suitable for use by qualified engineers and technical personnel.

2. Exclusions: FDs need not include the following items that may be required elsewhere in the Specifications:

   a. Drawings

b. Detailed schematics and wiring diagrams

c. Test plans, test procedures, and test reports

d. Software CDRL items required by this Section

e. FMECAs and the like

f. Other items deemed by SEPTA to be inappropriate or irrelevant

3. Searchable Format: The form of each FD shall consist of a single, independent file in PDF format that is computer searchable. The filename shall clearly convey the subject and revision level of the FD, and shall follow a format consistent across all FDs.

4. Integration of CDRLs into FDs: The purpose of the following requirements is to ensure that all important design information is readily available in the latter stages of the project.

a. General:

i. Each FD shall progressively incorporate all other CDRLs that are specific to the system or area concerned. Data sheets for all COTS items shall be included in the FD.

ii. Each such CDRL shall initially be handled as a separate, free-standing document, as is customary.

iii. Once the CDRL has reached a certain state of completeness, as specified below, its content shall be incorporated into the relevant FD.

iv. After that point, the CDRL shall cease to exist as a separate document, but its content and subject area shall continue to be updated as part of the FD.

b. Affected Items: The list of CDRLs to be integrated will vary from system to system, but generally will include those listed in the Contract Deliverables Requirements List (CDRL) section, of the relevant Specification sections, and those required in various places to be prepared for each system or functional area on the vehicle.

c. Details:

i. Before integration of a given CDRL, the relevant FD shall display a reference to the CDRL in lieu of redundant coverage of the CDRL's subject area.

ii. Integration of a CDRL into the FD shall commence once the CDRL has received the status of **approved** as Submitted, or as otherwise directed by the Engineer.

iii. The FD shall list the identity and revision level of each CDRL at the point at which it was first integrated into the FD.

iv. Bulky or repetitive portions of CDRLs shall be included as appendices or may be omitted with the Engineer's **approval**. CDRLs that are system-specific or area-specific, but appear on the list of exclusions(above), need not be integrated into the FD.

18.2.3.2 System Functional Descriptions (SFDs)

Comply with the following:

1. General: For each system, prepare and maintain an SFD providing a central reference for all engineering information about the structure, capabilities, functionality, and interfaces of the system. Content of the SFD shall be a significant input into the makeup of the Maintenance and Servicing Manual (Section 19, System Support).

2. Content: The SFD shall include the following information as appropriate for each system. Items in parentheses are intended as examples for guidance, rather than as rigid requirements.

    a. Structure (overview, arrangement, block diagrams, top-level schematics, isometric views)

    b. Performance (ratings, characteristic curves, load analyses)

    c. Functionality (explanations, sketches, matrices, details of algorithms, tutorial schematics)

    d. Protection (definitions, trip and lockout settings, reset requirements)

    e. Diagnostics (faults, snapshots, real-time data, self-tests, tests-on-demand)

    f. Software version history (reference list indicating what changed with each release) (include the relevant sections of each SVD (required per the Software Documentation section, below).

    g. Hardware (major assemblies, apparatus, valves, sensors, circuit boards, isometric views)

    h. Electrical interfaces (internal and external I/O, pinouts, voltage and current ratings)

    i. Hydraulic and other functional interfaces

    j. LRU listings

    k. SRAM

    l. SCIST

    m. PDST

18.2.3.3 Cab and Train Functional Description (CTFD)

Prepare and maintain a CTFD, providing a central reference for all engineering information about functions whose primary significance is at the train level. There shall be only one CTFD.

1. Content: The CTFD shall include the following information. Items in parentheses are intended as examples for guidance, rather than as rigid requirements.

    a. Structure (arrangement, locators, block diagrams, top-level schematics, isometric views)

    b. Trainline design, electric and pneumatic (overview, block diagrams, tutorial schematics, circuit design rationale)

    c. Cab controls and indicators (tabulation, locator, operation from a user perspective, operation of underlying circuits and functions from an engineering perspective)

d. Sequence-dependent interfaces among vehicles (air compressor sequencing, charging, consist sequence determination)

e. Data flow interfaces among vehicles (time synchronization, GPS data, diagnostic data buffering, and forwarding)

f. Other information of a similar nature as appropriate to the design

2. Exclusions: The CTFD shall not include information that is redundant with that included in the SFDs, or is relevant only to a single system.

3. All Finite Element Analyses (FEAs) shall be supplied per the requisite CDRLs listed in Section 03 – Vehicle-Body Structure.

4. All documentation contained in the FDR shall be continuously updated and submitted to the Engineer during the warranty period, including, but not limited to, drawings, technical specifications (FDs, SFRS), Inspection and Test Procedures, and software CDRL items.

5. If an IPDR is deemed necessary by the Engineer, the IPDR packages shall provide each major system supplier (including the Contractor, if it shall provide any of the major systems) with a clear and concise technical description of the work to be performed. The technical description shall address, at a minimum, the following items:

a. Project description

b. General notes

c. Schedule of CDRL items

d. FDs and all technical requirements conveyed to the suppliers

e. SFRS

f. List of items to be submitted

g. Reliability, Availability, Maintainability, and Safety (RAMS) requirements

h. Mock-ups and prototypes

i. Tests

j. Quality Assurance

k. Drawings and technical specifications

l. Bar coding and serialization

m. Manuals (Operator's, Maintenance, Tool and Test Equipment, Illustrated Parts Catalog, Integrated Schematics, Vehicle-Body Structural Repair, Interactive Electronic, and Training Program Manuals (Section 19, System Support)

n. Software Bill of Materials (SBOM) Template

o. Manual Technical Writer and Maintenance Engineer requirements

p. Training

q. Test equipment and special tools

r. Spare parts and life cycle maintenance

s. Contractor requirements

t. Software development

u. EMI/EMC Issues

v. Open Action Items Review (including a consolidated action item list)

6. The Contractor, with the assistance of its major system suppliers, shall conduct a PDR and FDR meeting that shall set forth the proposed design of each major system.

   a. A PDR and FDR meeting shall be held with each major system supplier and attended by SEPTA. The PDR and FDR meetings shall be used by the Contractor and its system suppliers to present the design of the systems to SEPTA, demonstrate compliance with the Specifications, and address SEPTA's comments and concerns before any manufacturing takes place.

   b. At the time of the FDR meeting, the PDR information shall be updated to finalize the design that, when accepted, shall then be ready for prototype manufacture, type testing, and FAI. FDR documentation shall continue to be updated until the design is **approved**.

   c. The PDR and FDR documentation shall include the following details:

      i. FDs

      ii. SFRS

      iii. Work Procedures, Design Implementation Data (including manufacturer's component and material specifications), Drawings, and Schematics

      iv. CDRL Status

      v. Specification Requirements and Other Requirements (including a traceability document to identify where Specification requirements are addressed to ensure that all requirements have been met)

      vi. LRU and SRU Identification

      vii. Open Action Items Review (including a consolidated action item list)

      viii. Specification Deviation(s) Review

      ix. EMI/EMC Analyses of Design and Test Requirements (Section 2, Design and Performance Criteria)

      x. RAMS

      xi. Flammability, Smoke, and Toxicity Reports (Section 16, Materials and Workmanship)

      xii. Test equipment and special tools

      xiii. Software Documents (as required by the Software Documentation section, below)

xiv. Final and Updated Master Test Plan (Section 15, Testing)

xv. Bar Coding and Serialization

xvi. Manuals Front End Analysis (PDR Only)

xvii. Technical Documentation, Manuals, Maintenance Requirements, and Parts

xviii. SBOM Samples from the Contractor and each subcontractor by PDR

d. All of the written design review documentation shall be presented in the English language. Submittal of written material at the PDR or FDR level that cannot be readily understood, at Engineer's discretion, shall be cause for return of that material to the Contractor and rescheduling of the PDR or FDR.

7. The Contractor and its suppliers shall provide test procedures for all tests, which shall include, but not be limited to, the following:

    a. Test Procedure number, revision level, and revision log

    b. Descriptive title

    c. Identity of Author, Verifier, Approver, and dates

    d. CDRLs reference

    e. Scope of test (Specification Reference)

    f. Purpose of test

    g. Effectivity Information

    h. List of test equipment required (calibration and certification of all test equipment shall be provided to SEPTA prior to conducting the test)

    i. Test setup

    j. Step-by-step test procedure

    k. Clearly defined pass/fail criteria

    l. Test Report data sheets that include pass/fail criteria to be completed during the test

    m. Box for test conclusion

8. The Contractor and its suppliers shall provide test reports for all tests, which shall include, but not be limited to, the following:

    a. Test Report number, revision level, and revision log

    b. Descriptive title

    c. Identity of Test Procedure and revision level used, and of unit tested, including software version

    d. Identity of Author, Verifier, and Approver, and dates

e. CDRLs register reference

f. Scope of test (Specification reference)

g. Purpose of test

h. Summary of test results and recommendation of status (pass/fail)

i. List of test equipment used and calibration status

j. Description of test setup

k. Step-by-step results of Test Procedure

l. Data records from test

9. The Contractor and its suppliers shall provide FAI documentation, which shall include, but not be limited to, the following:

a. FAI Procedure

b. **Approved** production drawings

c. Samples

d. Contractor's pre-FAI report

e. **Approved** Deviations and Waivers

f. Master Test Schedule

g. Detailed Test Plan/Test Procedure

h. STRs

i. SVVRt

j. SVD

k. Type Test Reports

l. Vendor Production Conformance Test Reports

m. Hardware and Software Configuration List

n. Pre-shipment procedure

o. Photographs

p. Production Final Inspection Reports

q. CDRLs required

r. Meeting open items

18.2.4 System Integration

The Contractor, as part of its responsibility for system design of the entire vehicle and all of its equipment, shall be responsible to SEPTA for proper interrelation, function, and system integration of all phases of all vehicle systems, their interrelation with all other parts of the vehicle, and their interrelation with the wayside and shop facilities.

1. Provide complete systems integration services during the design, manufacturing, and testing phases of the Contract. In concert with a full-time systems integrator, coordinate all electrical and mechanical interfaces between the different vehicle subsystems, the vehicle and the wayside and shop, and electrical interference control.

2. The system integration services shall include, but not be limited to:

    a. Data network integration, including hardware and protocols (Section 17, Controls, Networks, and MDS)

    b. Diagnostic system integration (Section 17)

    c. Propulsion and brake system interface and integration (Section 10, Propulsion System and Control, and Section 12, Friction Brake System)

    d. CBTC system interface and integration (Section 21, Communications Based Train Control)

    e. Communications systems (Section 13, Vehicle Communications Systems)

    f. Other vehicle system interface and integration

    g. Unit, and train interface

    h. Vehicle-to-wayside interface, including EMI/EMC (Section 2, Design and Performance Criteria, Section 17)

    i. Vehicle-to-shop facilities' interface

    j. System Safety Plan

    k. Manuals

    l. Reliability and Maintainability

    m. Reliability-based maintenance plan

    n. Train hardware and software safety

    o. Inspection, testing, and maintenance plan (Section 15, Testing)

    p. Training, qualification, and designation program

    q. Pre-revenue service acceptance testing plan

18.3 Microprocessor-Based Systems

18.3.1 Scope

This section provides requirements for the Contractor as well as its suppliers who are providing systems or components that include software.

1. All software provided under this Contract, including but not limited to the following, is subject to the requirements provided in this section:
    a. Resident within a microprocessor-controlled system
    b. Provided as part of test or interface equipment
    c. Provided for the purpose of post-download data analysis and processing
    d. Incorporated within training technology and manuals
    e. Non-generic BTE
2. These requirements apply to all systems that include processors or other programmable components such as programmable logic devices (PLDs).

18.3.2 General Requirements

Comply with the following:

1. Hardware and software requirements depend on the degree to which the hardware or software is custom designed for or applied to this project.
    a. "Commercially available" hardware or software shall be readily available in the US through retail and wholesale sources and shall be subject to documentation and training requirements of this section.
    b. "Non-commercially available" hardware or software is defined as being part of a standard product or developed or modified according to the requirements in this section. It shall be subject to all of the design, documentation, and training requirements of this section.
2. Software shall be applied, designed, or modified by implementing formal software processes, using modern programming techniques, and commonly available development environments and tools. As part of the formal processes, rigorous and documented testing, QA processes, and version controls shall be performed.
3. Software shall be reviewed as an integral part of each design review for any system that uses software. The correlation between design reviews and required software documentation CDRLs shall be as specified in Table 18-1.
4. Submit a list of Contract software, executing outside of embedded subsystems, that is incompatible with 64-bit processors.

18.3.3 Software Systems Functions and Features

18.3.3.1 Hardware Platform

Comply with the following:

1. Vehicle-borne and custom computer hardware shall be designed and constructed in accordance with the general electronic design principles specified in Section 9, Electrical Equipment, Section 16, Materials and Workmanship, and Section 17, Controls, Networks, and MDS.

2. Computers, whether portable or not, and microprocessor hardware shall be readily available through retail or wholesale outlets in the US for 15 years. They shall be from **approved** domestic manufacturers. If they are not available for 15 years, they shall be supported with replacement parts or be capable of being replaced with form/fit/function-compatible direct replacements.

3. All software and hardware delivered or developed under this Contract shall be capable of handling dates in the range from 2000 to 2099. The date data processing shall not experience abnormal ending or invalid or incorrect results from the hardware, software, data repository, or firmware in operation as part of SEPTA’s business processes. Each hardware, software, data repository, or firmware's date data interface shall support a four-digit year format.

4. Microprocessor-based systems shall be based on an established family of microprocessors in wide use in the control system industry and the rail industry. They shall be supported by a full range of software development languages and diagnostic programs.

5. Use of commercially available computer boards shall be specifically **approved** by the Engineer on a case-by-case basis. Such **approval** will be based upon a technical review of the product, product documentation, and a commercial assessment of product availability.

6. The computer shall be powered by dedicated, transformer-isolated power supplies driven from the low-voltage power supply (LVPS), if vehicle-borne.

7. A special algorithm shall be provided to ensure that computer shutdown and restart occur in a safe and predictable manner, that spurious faults are not generated during shutdown or restart, that stored diagnostic data is not lost during shutdown or restart, and that time-stamp integrity is maintained on all diagnostic data through any shutdown and restart process, including immediately after restart.

8. All processor system input and output signals shall be through isolation buffers. High-voltage inputs and outputs shall be isolated external to the microcomputer card rack. Low-voltage (battery and logic voltage level) inputs and outputs shall be isolated via buffer cards in or external to the microcomputer card rack. The isolation buffers shall accomplish the following:

    a. Protect and isolate the system from damage due to overvoltage, undervoltage, transients, shorts, and open circuits.

    b. Perform necessary voltage translations.

    c. Remove noise and undesired signals.

   d. Pre-processing to limit, discriminate, and format those signals that would otherwise require excessive processor time.

9. Isolation buffers shall consist of optical isolators, transformer isolators, and other circuits appropriate to the application.

10. Program code and fixed data shall be stored in reprogrammable non-volatile memory. SEPTA's preference is for flash memory.

11. EPROM windows shall be covered with labels that are opaque at the UV erasing wavelengths.

12. Software upgrades shall be performed using a password-protected function on the PTU. This requirement is not applicable to systems that are not reprogrammable by PTU. The time required to upload the entire software complement for a given system, including time to replace firmware embodied in FPGAs, CPLDs, and the like, shall be no more than 1 hour.

13. To minimize the number of individual batteries that shall be maintained, the use of battery backup shall be limited to the extent practical, and shall be subject to **approval**. Where **approved**, backup or standby batteries shall meet the following requirements:

    a. Rechargeable batteries shall be sized to retain data for at least six months without charging, and shall be located such that leakage cannot damage any control system components.

    b. Battery life shall be no less than five years, regardless of type.

    c. Systems using standby or backup batteries shall annunciate the need for battery replacement such that the battery continues to perform its function until it can be replaced at the next periodic maintenance. A "low battery" condition shall be annunciated.

    d. Batteries shall not be connected by soldering and shall be easily replaceable in the vehicle.

    e. Necessary RAM control data shall not depend on battery back-up, but shall be stored in non-volatile memory and "shadowed" to RAM for use.

14. The hardware shall be designed to allow program expansion without hardware modification. Expandability and capacity requirements are as follows:

    a. The memory needs of the installed software shall not use more than 50% of the installed memory capacity at Final Design Review. This requirement applies individually to each type of memory installed, whether it is EPROM, EEPROM, Flash PROM, RAM, or other types.

    b. Peak processing time demands shall not be greater than 50% of the available processor capacity.

    c. The hardware shall include spare input and output channels of each type used within the system, except for major output drivers where the quantity is fixed by the overall system design (e.g., traction motor semiconductors and sign character drivers). In addition, the architecture and assembly construction shall allow for the installation of additional I/O hardware.

15. Submit a plan for **approval** for carrying out software upgrade campaigns fleet-wide on an expedited basis.

    a. The plan shall incorporate provisions in individual systems, in the PTUs, BTEs, and in onboard networks, that will permit individual technicians to upload new software to multiple processors in a simultaneous or overlapping manner. The purpose of this requirement is to eliminate the idle or waiting time of each technician and thus to maximize use of SEPTA's resources when a software upgrade must be implemented urgently.

18.3.4 Operating Systems, Languages, and Compilers

Comply with the following:

1. Software may be written in a high-level language; languages such as C/C++, etc., are preferred. The language, and its implementation for the selected microprocessor system, shall be commercially available in English.

2. All languages and operating systems shall have an acceptable customer base (widespread use), and be **approved**.

3. The Contractor and its suppliers shall use the current versions of all software and of all operating systems available at the time of FDR. Obsolete operating systems shall not be used. If an operating system becomes obsolete (defined as no longer supported by its manufacturer) during the life of the Contract, the Contractor shall furnish to SEPTA a migration plan to a current operating system, which describes the consequences to all affected hardware and software.

4. Compilers and other software development tools shall be commercially available and shall be most recent versions fully supported by the tool supplier. Use of proprietary compilers is prohibited.

5. The use of proprietary communications protocols shall be **approved**. Proprietary protocols shall only be permitted if they are fully described in an ICD and if SEPTA is granted full rights to the use of the protocol. The ICDs shall be submitted for **approval**. Design, verification, and acceptance testing shall be to the finalized ICD and tests shall cover all ranges such as for timing defined in the ICD.

18.3.4.1 General Features

Software shall perform the following basic functions:

1. Implement the desired control scheme such that the specified performance is achieved.

2. Monitor inputs for unsafe, erroneous, or unknown conditions or combinations of conditions.

3. Sample input conditions at rates sufficient to detect and remedy unsafe or damaging conditions in the shortest possible time. Sampling rates and program execution times shall be such that the control system is not the limiting factor in response to unsafe or damaging conditions.

4. Limit output commands to safe levels regardless of the combination of input conditions.

5. Perform self-diagnostic routines and respond promptly, safely, and predictably to detected faults.

6. Respond safely and predictably when powering up or recovering from power interruptions. Detect power interruptions likely to have corrupted temporary storage and cause the system to re-initialize affected routines and temporary data. Detection of power interruptions may be by hardware.

7. Permit thorough interrogation of input, output, and internal conditions by external diagnostic equipment.

8. Present all user-accessible features and logs in clear English.

9. Software version numbers shall be included within the firmware code and shall be accessible to the system and vehicle-level diagnostic systems. If the software includes data or Operation Parameter Files (OPFs) that can be modified by the suppliers or by SEPTA, a modification to such files shall be reflected in the software version numbers.

10. Multi-chip programs shall self-test during initialization to ensure that the correct complement of chips is installed. The use of multi-chip programs shall be minimized to facilitate software upgrading.

11. Processor system parameters shall be adjustable during commissioning via PTU. During design review, appropriate parameters shall be suggested by suppliers for **approval**.

12. Watchdog timers or similar approaches shall be used to detect processor hung states and other processor execution failures. The systems shall then reset to a normal state. All such resets shall result in a fault being logged to facilitate problem investigation and repair. Watchdog resets shall not be considered part of normal acceptable operation of a system.

13. Software patches (quick/partial modification to fix a software bug) of embedded software are prohibited. For all software changes, generate complete software executables, meaning updated versions following the full development processes, including validation, defined in the **approved** supplier's and Contractor's plans.

18.3.5 Testing and Testability

All system or subsystem level features and functions of software systems that implement system or subsystem level requirements of the Specifications that are allocated to software, shall be testable on a system or subsystem level in the field:

1. Testing shall be performed using portable test equipment and procedures provided under this Contract.

2. Specific **approval** is required for any system or subsystem level feature specifically required by the Specifications that is not testable on a systems or subsystem level.

3. For features that are testable only off the vehicle with special equipment, the necessary equipment shall be furnished by the Contractor as test equipment (Section 19, System Support), and become the property of SEPTA. This equipment shall provide the logic, sequencing, and emulation necessary to verify that the software functions as intended. In lieu of separate equipment, appropriate test functions may be provided within the PTU.

4. Type tests of all processor systems shall verify the proper operation of all software features, including diagnostics:

    a. The type tests shall demonstrate that the system under test can successfully recognize and report all faults or events reported to the Monitoring and Diagnostic System.

    b. Where such tests may result in damage to the system hardware, the fault or event may be simulated to avoid damage to the hardware. Such testing shall be performed any time the software is changed prior to putting it into service.

5. Software validation (testing) shall be part of the total project testing process. Test procedures, testing, and test reports shall be subject to the review, witnessing and documentation processes. Software testing shall be a prerequisite to higher-level testing, such as system-level and vehicle-level tests. Software test procedures shall be **approved** prior to the execution of the tests.

6. After the initial version of software is installed on the vehicles, all software revisions shall be tested by the supplier in the supplier's facilities (i.e., laboratory) in accordance with its testing process and procedures.

    a. After successful completion of such tests, a test version of the software revision shall be placed on a limited number of vehicles and dynamically tested for a period of time as **approved**.

    b. Only after results of the dynamic tests on a limited number of vehicles have been **approved** shall a new software revision be applied to the fleet or any portion of the fleet.

    c. Application of any software revision to any portion of the fleet at any time shall be in conformity with the **approved** Modification and Configuration Control Plan (Section 20, Program Control and Quality Assurance).

18.3.6 Software Documentation

Comply with the following:

1. For non-commercially available software:

    a. Furnish sufficient documentation to permit SEPTA to fully comprehend and analyze the operation of the equipment in which the software is to be installed and to enable SEPTA to maintain and modify the software to correct problems, adapt it to changing requirements, add features, and port it to a new hardware platform.

    b. In any case, delivered documentation shall be sufficient to allow SEPTA to operate and change the software including, but not limited to, source code changes, parameter adjustment, and troubleshooting of software issues.

2. For Category A: For application-specific software and configuration files developed or adapted specifically for this Contract, software documentation shall be in accordance with IEEE Std 1558-2004, Procurement Type 5, and with the additional specified requirements.

3. For Category B: Application-independent software, that is, fixed system software that is used in multiple applications (e.g., operating systems), or defined as being part of a standard product line

(i.e., reused and unmodified), is subject to the documentation and process requirements of IEEE Std 1558-2004, Procurement Type 3. Category B software shall be of an existing, service-proven design.

4. Classification of software as Category A or B shall be subject to **approval**. In any case, Category B software shall be of an existing, service-proven design.

5. IEEE Std 1558-2004 references numerous IEEE Computer Society standards. The specified CDRLs shall comply with the indicated version of each referenced standard, with the exception of IEEE 830, which shall be 1998.

6. All documentation shall use names, acronyms, and units consistent with those in the Specifications and as defined in the SFD, and Interface Control Documents (ICD).

7. Ensure that the documentation produced provides for the straightforward traceability of requirements of the Specifications throughout the design documentation and including the final tests.

8. The problem reporting and corrective action process shall provide reports allowing the easy tracing of problems found at each development stage back to changes in the requirements, design, or implementation in source code.

9. Ensure ICDs are developed as specified in Section 18, Systems and Software Engineering, including ICDs required between Contractor-supplied equipment and SEPTA applications.

10. The placing of software design documentation details such as proprietary source code in an escrow account in lieu of submittal to the Engineer and SEPTA is permitted subject to **approval** by the Engineer provided that sufficient software information is provided (submitted and/or shown to an approved reviewer) to enable the Engineer to evaluate the overall system performance. In any case, delivered documentation shall be sufficient to allow SEPTA to operate and maintain the software including, but not limited to, parameter adjustment and troubleshooting of software issues.

11. Conduct a software escrow verification test and demonstration for all escrowed software. SEPTA reserves the right to witness such test.

    a. These tests, at a minimum, shall verify that all software, development tools, and Software Workstation Build Procedures have been escrowed to compile, link, or otherwise generate the firmware, object code, P-Code, executable code, or whatever is required to run on the vehicle system or portable test equipment, BTE, or other software-based system provided by the Contractor or its suppliers.

    b. The software items generated shall be demonstrated to be identical to the software released and in use.

12. The escrowed software design, documentation details, source code, etc., shall be made available to SEPTA for its own use for any of the following reasons:

    a. If the Contractor or its supplier is no longer in business, or no longer supports the product and has not transferred the rights to the design to another entity.

   b. If, based on an independent third-party assessment, the Contractor or its supplier no longer supports the product at a reasonable cost.

13. Submit the following documentation for **approval**:
    a. Single software documentation methodology for the project that complies with IEEE Std 1558
    b. SPMP
    c. SQAP
    d. SCMP
    e. SVVP
    f. SVVR

14. The Contractor's SVVP and SVVR, listed above, shall reflect the verification and validation related to integration of systems at the vehicle level.

15. The software suppliers shall submit the following documentation:
    a. SPMP
    b. SQAP
    c. STP
    d. SCMP
    e. SVVP
    f. SVVR
    g. SRTM
    h. Each supplier shall identify in a SCIST, that is eventually incorporated into the SFRS, each SCI by assigned part number. The SCIST shall identify all software used by the system including Category A, Category B, and Commercially Available Software. The SCIST shall also identify separately all software tools needed to produce the system software.
    i. For each SCI:
       i. SRS
       ii. SDD
       iii. STPr
       iv. STR
    j. For each system:
       i. SVD
       ii. SUM

18.3.7 Commercially Available Software

Comply with the following:

1. Some software supplied under this Contract may be commercially available to a wide variety of users. Examples include operating systems supplied by chip manufacturers and database software for wayside fault analysis.

2. Submit a list of software that is commercially available to the general public. The Engineer will determine which software will be classified as Commercially Available Software.

3. For Commercially Available Software, software documentation requirements are limited to the following:

    a. A description in the applicable SFD of the functions of the item and its interfaces.

    b. The original data storage/transfer media, functional and usage details

    c. All documentation provided with the software.

    d. All licenses required for SEPTA's site use

    e. Descriptions of any configuration or customization such as the selection of options or features or the setting of parameters

4. As part of the training program specified in Section 19, System Support, incorporate training on how the software is to be used in the specific situation for which it was provided.

18.3.8 Configuration Control

Comply with the following:

1. Develop and submit a Configuration Control Plan (CCP) for tracking software changes to individual vehicles on SEPTA’s property until Acceptance of the entire fleet.

    a. The CCP shall also control software on non-vehicle equipment such as PTUs, BTE, and the like, and shall include a mechanism to ensure continuing compatibility between vehicle software and non-vehicle software.

    b. The plan shall be consistent with the Contractor's approach to configuration control of hardware and require similar **approvals** and tests.

2. All software shall be identified by a name and a unique version number and date. The name shall identify the equipment into which the software is installed. Every change to software shall be reflected in an update to the version number and date.

3. Maintain a database of the software version of every software item on each vehicle and in each piece of non-vehicle equipment.

    a. Keep the database current at all times.

    b. The database application shall be capable of generating reports showing configuration of the following items in terms of software history and status:

i. Vehicle subsystem

ii. Complete vehicle

iii. Fleet

c. Make these reports available starting at delivery of the first car.

d. Maintain the CCP and the database application through completion of the Warranty period.

e. Provide the database to SEPTA at the end of the warranty period.

f. Configuration report documents shall include an indexed list of software licenses.

g. Furnish the software version status of every software item on the vehicle at the time of Conditional Acceptance/Acceptance of each vehicle.

h. Furnish the software version status of every software item on each piece of non-vehicle equipment at the time of Conditional Acceptance/ Acceptance of that piece of equipment.

4. Furnish a utility with all PTUs, BTEs, and Software Workstations by which a unique Version ID value can be calculated using CRC-32 on the executable file for each SCI. The calculated Version ID shall be included in the SVD of each software release.

5. Following installation of software, continue to provide software revisions when software is updated by the Contractor or by subcontractors. Keep revisions current until the end of the warranty period.

6. Submit all software versions referenced in the final software configuration to SEPTA at the time of acceptance of all vehicles.

18.4 Software Maintenance and Related Tools

SEPTA retains the right to perform software modifications on all Category A and B software. All such software for this vehicle shall be delivered to SEPTA in electronic format, except as specified above. Software tools to be provided to SEPTA shall include the following:

1. Provide software workstations, including all software and software development tools used by the suppliers.

    a. Minimize the number of different software workstations to the maximum extent practical by providing software workstations that can be used by multiple suppliers for the systems using software.

    b. The complement of equipment shall include the complete development environment (e.g., all compilers, assemblers, linkers, configuration management tools, in-circuit emulators, and other such tools that are used for software development).

    c. Furnish all associated manuals.

2. Development tools and software provided to SEPTA shall be the same version as used by the suppliers.

3. The development system shall allow software modifications and tests of all rail application-related software in this Contract, of all onboard diagnostic software and of all off-vehicle support equipment including, but not limited to, the PTU and Wayside Monitoring and Diagnostic System (WMDS) server and client software).

   a. The complete complement of software development/modification tools shall be delivered such that software modifications can, if desired, be made on-site during acceptance testing.

   b. Provide password protection for modifications to all safety-critical software (e.g., doors, CBTC, propulsion, and friction brakes.)

4. The equipment furnished shall provide for loading all necessary software, including executables, data files, and files for programmable devices. Loading rates shall be adequate to support SEPTA's maintenance needs.

5. The workstation and software documentation equipment shall be delivered, demonstrated, and proven to perform its function prior to acceptance of the first unit.

   a. The demonstration shall consist of:

      i. Creating the Workstation following the Software Workstation Build Procedures.

      ii. SEPTA's personnel using the workstation, source code files, and written instructions to create program files, which then must match the programs stored within the system's equipment.

      iii. A match or mismatch shall be determined by a comparison of the Version ID value generated by the CRC utility installed on the workstation with the Version ID value in the SVD for the software version.

18.5 Portable Test Unit Software

Comply with the following:

1. PTU software shall comply with the same requirements as other software as specified in the preceding sections.

2. Design of the PTU software shall include consideration of future ease of upgrade and ease of migration to newer replacement computers during the life of the cars, at no cost to the Authority. This includes the possible use of open systems and tools.

3. At the time of PDR, the operating systems used shall be discussed and fixed. The operating system must be supported by its manufacturer.

4. Two levels of passwords shall be provided, one allowing access to data for analysis and troubleshooting (maintenance function), and the other allowing modification or reloading of software (engineering function).

5. The PTU software application usability shall account for maintenance and engineering functions.

   a. The PTU software applications for each subsystem should be end-user-friendly with unambiguous display formats.

b. The navigation feature should include a help menu with content, index and search capabilities, and "tool tip" display for tool bar icons and categories.

c. The end user application displays should have easy-to-follow functionality that presents logically synthetic components with applicable headings.

d. The PTU software application shall have an interrogation functionality that will allow diagnostic displays and drill down capabilities.

e. The PTU software application shall automatically adapt to all standard PC screen sizes and resolutions.

f. The PTU shall include a client Push Technology functionality.

18.6 Bench Test Equipment Software

Comply with the following:

1. BTE software shall comply with the same requirements as other software as detailed in the preceding sections.
2. Design of the BTE shall include consideration of future ease of upgrade and ease of migration to newer replacement computers during the life of the vehicles; this includes the possible use of open systems and tools.
3. At the time of PDR, the operating systems used shall be discussed and fixed.
4. Two levels of passwords shall be provided, one allowing access to data for analysis and troubleshooting and the other allowing modification or reloading of software.

18.7 Software Quality Assurance Audits

The SQA process may be integrated with the overall project QA process and as such, QA and SQA audits need not be separate events. At its discretion, SEPTA will participate as a member of the SQA audit team.

The Contractor shall conduct, at a minimum, the following SQA audits at the supplier’s location for each supplier (entity/entities providing the software):

1. Qualification Audit (external suppliers only)
2. Initial Audit
3. In-Process Audit
4. Functional Audit

The status and details of audits shall be reported as a section in the monthly progress update reports specified in Section 20, Program Control and Quality Assurance.

If the Contractor/supplier has demonstrated process capability by providing the results of a current, independent SCAMPI Class A Appraisal, which documents a rating of Capability Level 2 in the Target Profile

, the results of the in-process audits performed as part of the supplier’s or sub-supplier's managed process (e.g., audit reports that include identified non-compliances) shall be submitted in lieu of the Contractor conducting the in-process audit.

18.8 Contract Deliverables Requirements List (CDRL)

18-1 SCAMPI Class A Appraisal Disclosure Statement, and Final Findings Presentation
18-2 Benchmark Appraisal Disclosure Statement, Final Findings Presentation, and Performance Report
18-3 Project-Specific Remedial Action Plan and Evaluation Appraisal Results
18-4 Standard Software Documentation Methodology
18-5 System Function Requirements Specification (SFRS)
18-6 Interface Control Document (ICD)
18-7 Cab and Train Functional Description (CTFD)
18-8 System Functional Description (Individual System)
18-9 Software Project Management Plan (SPMP)
18-10 Software Quality Assurance Plan (SQAP)
18-11 Software Configuration Management Plan (SCMP)
18-12 Software Verification and Validation Plan (SVVP)
18-13 Software Verification and Validation Report (SVVR)
18-14 Software Test Plan (STP)
18-15 Software Requirements Specification (SRS)
18-16 Software Design Description (SDD)
18-17 Database Design Description (DDD)
18-18 Software Requirements Traceability Matrix (SRTM)
18-19 Software Test Procedure (STPr)
18-20 Software Test Report (STR)
18-21 Software Version Description (SVD)
18-22 Software User Manual (SUM)
18-23 Software Workstation Build Procedures

18.9 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance, and Table 18-1, Document Delivery Schedule.

18-1 SCAMPI Class A Appraisal Disclosure Statement, and Final Findings Presentation:

1. See requirements, above (see Contractor and Supplier Qualification section).
2. Submit either CDRL 18-1 or CDRL 18-2

18-2 Benchmark Appraisal Disclosure Statement, Final Findings Presentation, and Performance Report:

1. See requirements, above (see Contractor and Supplier Qualification section).
2. Submit either CDRL 18-1 or CDRL 18-2

18-3 Project-Specific Remedial Action Plan and Evaluation Appraisal Results:

1. See requirements, above (see Contractor and Supplier Qualification section).

2. Only required if CDRL 18-1 or CDRL 18-2 is not submitted.

18-4 Standard Software Documentation Methodology:

1. See requirements, above (see Software Documentation section).

18-5 System Function Requirements Specification (SFRS):

1. See requirements, above (see Systems Engineering section).

18-6 Interface Control Document (ICD):

1. Develop a vehicle-level ICD that includes the same systems as the vehicle-level SFD.

2. Develop system-level ICDs (see Systems Engineering section).

18-7 Cab and Train Functional Description (CTFD):

1. See requirements, above (see Cab and Train Functional Description (CTFD) section).

2. Furnish a high-level SFD to act as a roadmap to integration of individual systems into the vehicle.

    a. Clearly define interfaces and interactions of each system with the vehicle and with other systems, identify ICDs, and reference the ICDs provided.

    b. Use terminology consistent with terminology of the Specifications and define names for subsystems and the interfaces between them to ensure consistent terminology used by all suppliers.

3. Include the following:

    a. Cover sheet with name, document number, and revision level per requirements of Section 20, Program Control and Quality Assurance.

    b. List of reference documents.

    c. Defined scope, purpose, introduction, and list of abbreviations and acronyms and their meanings.

4. At a minimum, include the following systems:

    a. Operator’s controls

    b. Passenger doors and bridge plates

    c. HVAC

    d. Lighting

e. Electrical

f. Propulsion

g. Brakes

h. Vehicle Communication Systems

i. CBTC

j. Electronic Controls and MDS

18-8 System Functional Description (Individual System):

1. Submit for each individual system. If individual systems are not submitted all at one time, comply with the requirements of Section 20, Program Control and Quality Assurance, for numbering and documentation for CDRL packages that are submitted in more than one part.
2. See requirements, above (see System Functional Descriptions (SFDs) section).

18-9 Software Project Management Plan (SPMP):

1. Comply with IEEE Std 1558-2004.
2. Details shall be furnished describing monitoring of supplier activities to ensure development tasks are completed and delivery requirements are met for each development phase from concept development to warranty support.
3. It shall include a schedule showing the key tasks/milestones defined for the software development.
4. A Gantt chart shall be used showing the timing and interrelationships between tasks.
5. The schedule shall include the allocation of time and resources for realistically addressing issues raised by internal reviews, Contractor reviews, or by the Engineer.
6. It shall include detailed descriptions of the metrics to be used to monitor and control the project. This shall include monitoring project progress on intermediate tasks and triggering management corrective actions with sufficient time to ensure required deliveries are met.

18-10 Software Quality Assurance Plan (SQAP):

1. Comply with IEEE Std 1558-2004.
2. The scope of this document shall cover the entire software lifecycle for the project.
3. It shall describe the software quality assurance responsibilities of the Contractor and be linked to the suppliers' SQAPs.
4. It shall describe the procedures used to conduct and the timing of software quality audits for suppliers and subcontractors.

5. It shall describe what quality metrics will be produced and how they will be reported to the Engineer.

18-11 Software Configuration Management Plan (SCMP):

1. Comply with IEEE 1558-2004.

18-12 Software Verification and Validation Plan (SVVP):

1. Comply with IEEE 1558-2004.

18-13 Software Verification and Validation Report (SVVR):

1. An SVVR shall be comprised of a collection of the actual results of having performed the software V&V activities.

2. Provide an SVVR with each release of software.

18-14 Software Test Plan (STP):

1. Comply with IEEE 1558-2004.

18-15 Software Requirements Specification (SRS):

1. Comply with IEEE Std 1558-2004.

2. Assign a unique requirement identifier to each software requirement.

18-16 Software Design Description (SDD):

1. Comply with IEEE 1558-2004.

18-17 Database Design Description (DDD):

1. Applicable only when a database is being used.

2. Comply with IEEE 1558-2004.

18-18 Software Requirements Traceability Matrix (SRTM):

1. Comply with IEEE Std 1558-2004.

2. The information in the “Source Document Reference” column may be taken from the SFRS, ICD, or identified as “internal” meaning that it is a system-specific requirement of the supplier.

18-19 Software Test Procedure (STPr):

1. Comply with IEEE 1558-2004.

2. The STPr shall include the pass/fail criteria for each test case/step.

18-20 Software Test Report (STR):

1. Comply with IEEE 1558-2004.
2. The STR shall indicate the version of software that was tested.

18-21 Software Version Description (SVD):

1. Comply with IEEE Std 1558-2004.
2. Provide an SVD with each software release.

18-22 Software User Manual (SUM):

1. Comply with IEEE 1558-2004.

18-23 Software Workstation Build Procedure

1. See requirements, above (see Software Documentation section)

18.10 Referenced Standards

The following standards, handbook, and model are referenced in this Section:

IEEE Std 830-1998	Recommended Practice for Software Requirements Specifications
IEEE Std 1558-2004	Standard for Software Documentation for Rail Equipment and Systems
INCOSE-TP-2003-002-03.2.2	International Council on Systems Engineering's (INCOSE) Systems Engineering Handbook
CMMI^{SM}-DEV, v1.3	Capability Maturity Model Integration for Development, v1.3
CMMI^{SM}-DEV, v2.0	Capability Maturity Model Integration for Development, v2.0

END OF SECTION

Table of Contents

Table of Tables

19.1 Scope

This Section outlines system support requirements for the vehicle and each system. System support design shall align with SEPTA's Vehicle Engineering and Maintenance organization and infrastructure. System support for the entire vehicle and each system shall be included during each of the design review stages listed in Section 20, Program Control and Quality Assurance.

A system support analysis shall be conducted by the Contractor and all subsystem suppliers of available and planned resources, conducted via site surveys and investigations to ensure that all support risks are eliminated before delivery of support equipment occurs.

The Contractor and all subsystem suppliers shall treat SEPTA as an authorized repair agent. As such, all relevant and necessary documentation needed to test and perform repairs to components, modules, and systems shall be made available to SEPTA as a requirement of Contract. This includes all documentation necessary to repair modules and units to the most basic device level, including repairs to all circuit-board mounted devices, whether circuits boards are multilayered or not. The Contractor and its subcomponent suppliers shall not obfuscate or alter component or devices so as to limit multi-vendor sourcing of commercially available devices and components.

19.2 Manuals and Catalogs

19.2.1 Manual Schedule and Quantities

Furnish manuals for use by Operators and maintenance personnel in accordance with the requirements of this Section:

1. Draft manuals shall be sufficiently complete for SEPTA to perform all maintenance and troubleshooting activities.
2. Furnish drafts and final copies of the manuals in accordance with the following schedule:

TABLE 19-1, MANUAL AND CATALOG DELIVERY REQUIREMENTS			
Manual Type	**Deliver First Drafts No Later Than:**	**Deliver Final Manuals (Hard Copy and Electronic) No Later Than:**	**Hard Copy Quantities of Final Manuals**
Operator's Instruction and Troubleshooting Manual	18 months after NTP (200 Hard Copies + Electronic)	1 year after first vehicle delivery	1250
Preventive Maintenance and Servicing Manual	18 months after NTP (Electronic Only)	1 year after first vehicle delivery	30
Heavy Repair Manual	18 months after NTP (Electronic Only)	1 year after first vehicle delivery	30
Illustrated Parts Catalog	18 months after NTP (Electronic Only)	1 year after first vehicle delivery	60
Training Manuals	2 months before start of training (Electronic Only)	1 year after first vehicle delivery	One per student
Special Tools and Diagnostic Equipment Manuals	18 months after NTP (Electronic Only)	1 year after first vehicle delivery	One per unit supplied
Integrated Schematic Diagrams for Troubleshooting	18 months after NTP (Electronic Only)	1 year after first vehicle delivery	120

19.2.2 Manual General Requirements and Format

19.2.2.1 General Requirements

Comply with the following requirements for each specified manual:

1. Organize the manual such that the vehicle is treated as an integrated system and not as a grouping of disassociated parts.

2. Develop following the guidelines given in APTA PR-IM-RP-002-98.

3. Highlight safety precautions to be taken by operating and service personnel while operating vehicles and performing maintenance and servicing operations.

4. Produce a manual specific to this Contract that accurately represents the completed as-built vehicle, including but not limited to Contract-specific maintenance instructions, parts, wiring schematics, wiring diagrams, hydraulic schematics, piping diagrams, and component physical layouts.

5. Following the issue of each publication, furnish revised pages covering any changes, whether required by change of design or procedures or due to error. Keep these revisions current (revise minimum every 6 months) during the General Warranty period.

19.2.2.2 Hard Copy Format

Professionally produce each specified manual and comply with the following requirements:

1. Furnish as a bound book with cover or in a heavy duty, locking, D-ring-type three-ring binder.
2. Divide and tabulate into logical sections and subsections.
3. Include a table of contents at the front of the manual.
4. Print on quality paper meeting the following requirements:
    a. Tear-resistant
    b. Waterproof
    c. Grease, chemical, and stain resistant
    d. Polyester based synthetic, such as Revlar, by Relyco, or paper with similar qualities, as **approved**
    e. Minimum 5 mil thickness

19.2.2.3 Soft Copy Format

Submit each specified manual on electronic media in portable document format (PDF) and with editable masters. Editing software and five licenses to be provided to SEPTA for future revisions. Comply with the following requirements when creating PDF version of each manual:

1. Create searchable, zoomable PDF directly from native format, not by scanning hard copy documents.
2. Create with sufficient resolution to allow zooming of graphics without loss of quality or resolution.
3. Size PDF the same as hard copy version to allow SEPTA to easily print new hard copy versions from electronic media without resizing PDFs.
4. Create a hierarchy of bookmarks, with each major section as a top-level bookmark, and subsections as bookmark subheadings. Bookmarks shall match the structure of the table of contents and include the headings and subheadings in the same hierarchical structure.
5. Create links via the table of contents and throughout the documents, where applicable, to necessary drawings and text for ease of navigation to corresponding information.

Revise electronic media versions in accordance with hard copy manual revisions.

19.2.2.4 Content

See the Contract Deliverables Requirements section, below, for details of each manual to be submitted.

19.3 Special Tools and Diagnostic Equipment

19.3.1 General

Furnish all special tools necessary to perform required maintenance, inspection, troubleshooting, and repairs as defined in the Contractor’s maintenance manuals.

Furnish all equipment specified in this Section for comprehensive in-service maintenance, inspection, troubleshooting, repair, and testing of vehicles.

Furnish all drawings of each special tool provided to SEPTA in the Special Tools and Diagnostic Equipment Manual.

19.3.2 Delivery Schedule

Comply with the following delivery requirements:

1. Deliver special tools and diagnostic equipment at the same time as final copies of the Special Tools and Test Equipment Manuals specified above.
2. If not furnished before scheduled maintenance training, furnish minimum one complete set of special tools and diagnostic equipment necessary to service, maintain, and overhaul each system for use in the training program, such as the following:
    a. Jigs
    b. Fixtures
    c. Meters
    d. Gauges
    e. Vacuum pumps
    f. Temperature sensing devices

19.3.3 Special Tools

Special tools include, but are not limited to the following tools and equipment that are not commonly available from commercial tool suppliers and are necessary to maintain, repair, overhaul, assemble, and disassemble the vehicle or subsystems; or rerail the vehicle:

1. Jigs
2. Fixtures
3. Gauges
4. Equipment
5. Hand tools
6. Power tools

7. Non-standard rerailing tools

8. Tools necessary to lock articulations during jacking, if required

In addition, furnish tools that are commonly available from commercial tool suppliers and necessary to perform required maintenance, that have a per unit U.S. price of $2,000 or more.

At a minimum, furnish the following special tools:

1. Tools to activate tamper-proof fasteners and access panels

2. Vehicle jacking adapters (if used)

3. Door System:

   a. Gauges and jigs required for door installation and adjustments

   b. Obstruction detection tools including force gauge

4. HVAC System:

   a. Vacuum pump

   b. Refrigeration recovery and charging test manifold

   c. Holding fixture

   d. Leak tester, electronic

   e. HVAC unit lifting fixture:

      - Furnish minimum six for each type and size of unit
      - See Section 7, Heating, Ventilating, and Air Conditioning, for requirements

   f. HVAC unit storage frames:

      - Furnish minimum quantity necessary to store quantity of spare units plus two
      - See Section 7 for requirements

5. Propulsion System:

   a. Non-standard wrenches and gauges

   b. Pantograph manual operation tool

6. Truck Assembly:

   a. Tools for gearbox and coupling disassembly and re-assembly

   b. Journal-bearing puller

   c. Truck assembly stand

   d. Truck alignment jigs

   e. Wheel tire removal and installation tools

7. Friction Brake System:

   a. Caliper assembly tools

   b. Actuator assembly tools

   c. System bleeding & filtering equipment

   d. Accumulator servicing gauge and fittings

   e. Vericom V-SENSE DAQ

19.3.4 Non-PC Portable Test Equipment

Comply with the following:

1. All non-PC portable test equipment shall be furnished with the following as part of the maintenance manuals:

   a. Intended use instructions for each device.

   b. Drawings, schematics, diagrams, and part information of each piece of test equipment.

   c. Calibration and repair instructions for each device.

2. The Contractor shall make all modifications to the test equipment that are required due to changes made to the vehicles or any of its systems.

3. All non-PC portable test equipment shall comply with the following:

   a. Shall be durable and suitable for shop use, shall have water-resistant seals and switches, and shall have prior successful experience in a similar environment.

   b. Shall not exceed 15.8 kg (35 lb).

   c. Shall make use of quick disconnect multi-pin connectors as specified in section 16, Materials and Workmanship.

   d. Shall be powered by the vehicle’s LVPS.

4. All non-PC portable test equipment shall be **approved** by the Engineer.

5. All non-PC portable test equipment shall be delivered by the tenth production vehicle.

6. The Contractor shall fully demonstrate the function of each type of test equipment furnished once delivered and set up in the SEPTA facility.

19.3.5 Portable Test Units (PTUs)

19.3.5.1 PTU Hardware

Comply with the following:

1. PTU type: Laptop computer, using latest version of Windows operating system in use at time of design commencement, or an **approved** alternative as selected by the Engineer.
    a. PTU shall be durable and suitable for shop use, shall have water-resistant seals and switches, and shall have prior successful experience in a similar environment. The PTU shall be **approved** by the Engineer.
    b. PTU shall have highest performance-level systems (processing speed, available RAM, hard drive type, etc.) available in the commercial marketplace.
2. PTU connections:
    a. Ethernet port using RJ45connector, M12 connector, or alternate as **approved** by the Engineer.
    b. Minimum two USB ports.
    c. Where other interfaces are **approved,** provide all necessary interface adapters and interface software.
    d. Connection of external apparatuses shall not be required, unless approved by the Engineer.
    e. No high-voltage or high-current connections shall be permitted between the vehicle and the PTU.
    f. It shall not be necessary to disconnect any component on the vehicle in order to calibrate the PTU.

19.3.5.2 PTU Software

Comply with the following:

1. Provide laptop software that is not copy-protected, does not require external validating devices such as "dongles", and can be freely copied by SEPTA onto SEPTA's computers.
2. Design PTU software for future ease of upgrade and ease of migration to newer replacement computers during the life of the vehicles, at no cost to SEPTA. This includes the possible use of open systems and tools.
3. For custom software resident in PTUs, SEPTA shall be given a license at no cost for unlimited use and copying of the software for approved purposes of the Contract.
3. For software requiring a license, furnish software licenses with a term no less than the service life of the vehicle, as specified in Section 2, Design and Performance Criteria, with an option for extensions. Licenses shall not be linked to specific hardware serial numbers.

4. PTU shall incorporate open source software tools, such as the network protocol analyzer WireShark, in order to enhance the total PTU diagnostic capabilities.

5. The specified requirements for revisions to vehicle software in Section 18, Systems and Software Engineering, apply also to PTU software.

6. PTU software updates shall have forward and backward compatibility when connected to the vehicle software, or software updates may be made through the use of a web based interface. No special cables or wiring shall be required to upload new software or run or copy diagnostic programs.

7. Furnish back-up copies of all PTU software to SEPTA.

8. All PTU software documentation shall be furnished per Section 18, Systems and Software Engineering.

9. All PTU software shall be subject to the Approved configuration control plan.

10. Provide PTU software for each system requiring adjustment or diagnostics, including the following as a minimum:

    a. Door system

    b. Bridge plate system

    c. HVAC

    d. Auxiliary ac inverter

    e. DC low-voltage power supply (LVPS)

    f. Propulsion

    g. Friction brake

    h. Load leveling

    i. Communication systems, including PA, intercom, APIS, CCTV, GPS, Event Recorder, APC, AVL, TWC, ATP, and Operator interface.

    j. Vehicle network

    k. Monitoring and diagnostic system

    l. CBTC

    m. All systems making use of a microprocessor

19.3.5.3 PTU Quantity

Comply with the following:

1. Furnish 30 PTUs.

2. See Section 17, Controls, Networks and MDS, for one additional PTU, the Protocol Analyzer PTU.

3. Furnish with each unit:

    a. All connectors, cables, and adapters necessary to communicate with onboard systems from the PTU.

    b. A case.

    c. Two extra sets of extended life rechargeable batteries.

4. Furnish three PTUs before delivery of the first pilot vehicle.

5. All equipment shall be registered by the purchaser in the name of SEPTA as directed by the Engineer.

19.3.6 Bench Test Equipment (BTE)

19.3.6.1 General

Comply with the following:

1. Provide two complete sets of bench test equipment (BTE) and procedures to test and troubleshoot all basic functionality of vehicle systems' LLRUs in a back shop environment.

    a. Each BTE shall be a standalone device unless **approved**. If a consolidated BTE approach is **approved** the contractor shall**:**

        - Increase the number of required sets of BTE by 100% (i.e. 2 complete sets)

        - Demonstrate effective testing, troubleshooting, and calibration at the unit, module, and printed circuit board levels for all equipment.

        - Provide one complete and fully operational set of LRUs and LLRUs to the BTE system integrator(s) to be utilized in the development of the BTEs.

2. Supply all the detailed design information with test specifications for each level of LRU and LLRU to SEPTA and the selected test system integrator.BTE shall be off the vehicle, and be provided for all of the system components that cannot be evaluated by common test equipment, such as multimeters.

3. All BTE shall be designed for ease of operation and set up for testing.

4. Survey SEPTA's facilities and coordinate with SEPTA (for space, power and air supplies, and cleanliness etc.), to ensure compatibility of the BTE design with SEPTA's Shop facilities.

19.3.6.2 Required BTE

At a minimum, provide test equipment for the following:

1. Door operator and controller.

2. All Contractor-provided communication systems, including PA, intercom, APIS, CCTV, GPS, event recorder, APC, AVL, TWC, ATP, all displays, and Operator interfaces.
3. Vehicle network equipment.
4. Monitoring and diagnostic system, if distinct from vehicle network equipment.
5. Propulsion controls, traction motors, traction control units, friction brake controls, track brakes, all power converter and inverter units, wheel slide control units, etc.
6. All contractor-provided circuit boards.
7. Auxiliary and low-voltage power control units.
8. HVAC control units.
9. CBTC control units and ancillary equipment.
10. All electronics, electrical, hydraulic, and electromechanical units not identified above or in other sections.

19.3.6.3 BTE Performance and Features

Comply with the following:

1. Test equipment shall troubleshoot down to the LLRU component level.
2. Provide an emergency stop button on all test equipment that shall remove power from both the test equipment and the unit under test.
3. BTEs shall use automated testing to the greatest extent possible.
4. Test equipment shall allow for testing over full range of operating conditions.
5. Where inputs or outputs are via network connections, provide switches, gateways, and similar, as necessary, such that inputs can be produced and read by laptop computer.

19.3.6.4 BTE Accessories and Documentation

Include, at a minimum, the following:

1. Power supplies, operating from 110 or 220 Vac or shop-power compatible, providing sufficient power and type for all equipment.
2. Connectors and cabling to apply power to devices-under-test (DUTs) and test equipment.
3. Connectors and cabling to apply control signals, fixed or variable as appropriate, to DUTs.
4. Connectors and cabling to measure or monitor outputs.
5. Test equipment as necessary to view outputs that are not visual or audible.

6. Known good system units, golden units, which are marked in a distinct manner such that the unit may not be removed from the bench test equipment and used for operating.

7. Test procedures in written and electronic form.

8. Calibration instructions for all test equipment.

19.3.6.5 BTE Software

Comply with the following:

1. For software requiring a license, furnish software licenses with a term no less than the service life of the vehicle, as specified in Section 2, Design and Performance Criteria, with an option for extensions. Licenses shall not be linked to specific hardware serial numbers.

2. For custom software resident in BTEs, SEPTA shall be given a license at no cost for unlimited use and copying of the software for approved purposes of the Contract.

3. BTE software shall be subject to the **approved** configuration control plan.

4. Furnish all BTE software documentation.

19.3.6.5.1 Non-HPCU Test Equipment

Comply with the requirements specified above for BTE. In addition, provide, at a minimum, the following:

1. Ten sets of test equipment

2. All required chargers, cables, and connectors, etc.

3. All necessary instructions to operate this equipment.

4. All necessary software to operate this equipment.

19.3.6.6 Hydraulic Test Stand

Provide six integrated test stands to verify proper operation of friction brake HPCUs, calipers, and related hydraulic components. Include the following:

1. A hydraulic pressure source, variable over the full operating range of the HPCU. This may be a known-good HPCU.

2. Equipment to test HPCU operation. This is preferred to be a known-good ECU, or an ECU modified for this purpose.

3. Electronic controls to produce test conditions, and display and record results. This is preferred to be test software installed on a laptop computer, connected to the diagnostic port of the test stand ECU.

4. A power supply, providing sufficient power and type (ac and dc) to power all specified components, and appropriate cabling and connectors. Input power may be 110 or 220 Vac.

5. Calibrated hydraulic gauges or transducers to verify test pressures, and check transducers of components under test

6. Cabling and connectors as necessary for all tests.

7. Valves, piping, connectors, fittings, and similar, as necessary to make all needed connections.

8. Hydraulic filters sufficient to prevent contamination of test equipment and DUTs.

9. Brackets and structures, as necessary to safely mount, test, and disassemble DUTs, including calipers, on the test stand.

10. A load cell assembly for caliper force measurements.

11. Test brake pads of various thickness to verify slack adjuster functions and caliper forces over full range of pad and disk wear.

12. A drain pan and reservoir integrated into the test stand.

13. Test procedures in written and electronic form, including test stand maintenance.

19.3.6.7 HVAC Test Stand

Provide six integrated test stands to test and repair HVAC units. Include the following:

1. A stand suitable to safely mount the unit and access internal components.

2. A 120 Vac/24 Vdc supply of appropriate power and regulation for the DUT, with local circuit protection and controls to turn power on or off.

3. An ac input of correct voltage, frequency, and power, derived from the Shop's ac utility voltage. Include transformers, converters, and other components as necessary for the Shop three-phase ac interface. Include local circuit protection and controls to turn ac power on and off.

4. Test gauges, and temperature sensors.

5. Vacuum pump.

6. Refrigeration recovery and charging test manifold.

7. Software for PTU, if different than normal HVAC PTU software.

8. Variable resistors or other appropriate devices to inject temperature signals into the controller.

9. Cabling and connectors as necessary for all tests.

10. Test procedures in written and electronic form, including test stand maintenance.

19.4 Training

19.4.1 General

The following requirements apply to all types of training described in this section:

1. The duration of training and quantities of staff to be trained specified in this Section are SEPTA's estimates only. The Engineer will be the sole judge of the adequacy of the training plan offered.
2. Work closely with SEPTA's staff as training materials are being developed to ensure SEPTA standards are being met with respect to course organization, content, and overall quality of training materials.
3. All training materials, such as training aids and lesson plans, shall become the property of SEPTA at the completion of the training program.
4. SEPTA reserves the right to video tape training activities for use by SEPTA in later training programs.
5. Training programs shall be developed following the guidelines given in APTA-RT-RMT-RP-001-10.
6. SEPTA reserves the right to perform an audit of any and all courses, at The Engineer's discretion.

19.4.2 Training Program Description

Comply with the following general requirements:

1. Location: At SEPTA's facilities
2. Type of training: Classroom and hands-on.
3. Training categories:
    a. Operator training
    b. Maintenance training
4. Trainees: Instructors, supervisors, Operators, mechanics, and technicians, as selected by SEPTA.
    a. SEPTA may use a train-the-trainer approach, in which SEPTA training staff participate in training as students, and are then observed as trainers.
5. Training materials: Furnish the following as a minimum:
    a. Specified training manuals
    b. Other training aids as required to impart the essential knowledge to trainees
    c. Accurate and up-to-date reference materials

6. Testing:

   a. Design and conduct written and practical tests at suitable points in each course to determine the extent to which trainees have retained the course material and can apply the information.

   b. Document all written and practical test scores and furnish to SEPTA.

19.4.3 Operator Training

Comply with the following requirements for Operator training:

1. Scope: Include basic vehicle operation and how to detect and resolve in-service problems and emergencies.

2. Initial training:

   a. Within 10 days after delivery of the first vehicle, train one group of three Operators and two operations trainers.

   b. This group will come from the core team of Operators for the vehicle test program.

   c. Furnish a vehicle for this purpose and ensure that all applicable systems are properly operating.

3. Additional training: Train a total of 20 Operators, including those trained in the initial training, within the first 90 days after delivery of the first vehicle and 150 Operators within the first 360 days after delivery of the first vehicle.

19.4.4 Maintenance Training

19.4.4.1 Schedule and Duration

Furnish the following maintenance training for each of the subjects listed under Specific Contents below:

1. Initial training: Upon delivery of the first vehicle, complete training for one group of up to five trainees.

2. Additional training: After delivery of the first vehicle, train an additional five trainees.

3. Refresher training: Conduct one year after delivery of the last vehicle.

Time period:

1. Conduct the initial and additional training over a period of maximum 52 weeks.

2. Conduct the refresher training over a period of maximum 52 weeks.

Training hours:

1. Initial and additional training: While the requirement is to provide instruction for the entirety of the agreed upon course materials, a minimum of 2720 instructor training hours are to be provided.

2. Refresher training: While the requirement is to provide instruction for the entirety of the agreed upon course materials, a minimum of 240 instructor training hours, 120 classroom and 120 hands-on hours are to be provided.

19.4.4.2 Description

Comply with the following requirements for maintenance training:

1. Scope: Include all systems and subsystems provided under this Contract.
2. Include operations training for maintenance personnel to have the ability to operate the vehicle around shops, yards, and streets.
3. Maintenance types: Include preventive, corrective, and overhaul of components and assemblies.
4. Minimum maintenance training outline:
    a. Introduction to the equipment, including terminology, identification of major components and their location on the vehicle
    b. Detailed theory of operation
    c. Preventive maintenance:
        - Lubrication schedules
        - Adjustments
        - Tolerance limits
        - Inspection criteria
        - Recommendation for test frequency
        - Methods for testing, including instruments required
        - Filter change schedule
    d. Troubleshooting:
        - Problem symptoms
        - Troubleshooting techniques
        - Repair procedures
    e. Removal and replacement of parts and components from the vehicle
    f. Disassembly and reassembly for the purpose of component familiarity and any special processes
    g. Instruction in the use of all special tools and processes
    h. Overhaul of components and assemblies

5. Depth of training:

    a. Include sufficient detail such that trainees can successfully perform all maintenance and overhaul tasks presented down to the LLRU.

    b. Give trainees the opportunity to perform the more complex maintenance functions on the vehicle and in the Shop.

    c. Include training for equipment that uses new hardware and software technologies.

    d. Troubleshooting:

        - Instruct trainees in how to troubleshoot systems using appropriate subsystem test devices to locate and remedy faults.
        - Instruct trainees in how to troubleshoot systems to remove and replace to the LLRU.
        - Artificially introduce faults into equipment as needed to furnish adequate troubleshooting training.

6. Field instruction: Include both on-vehicle demonstrations and demonstrations of basic overhaul procedures using equipment in the Shop.

19.4.4.3 Specific Content

Furnish in-depth instruction addressing the following systems and components as a minimum:

1. Air conditioning and heating systems, including their controls
2. Auxiliary ac inverter
3. DC LVPS and battery
4. Braking system, including load leveling, sanding, and controls
5. Communications system
6. Network controls
7. Train signal and control system
8. Monitoring and diagnostic system
9. Lighting controls
10. Propulsion system, including traction motors and controls, and propulsion power converter and inverter
11. Trucks, including bearings, bearing surfaces, gear units, frame, suspensions, and shock absorbers
12. Door operators and controls
13. Bridge plate operators and controls

14. Removal, replacement, and adjustment of vehicle body materials and equipment, such as the following:
    a. Glazing and vandal film
    b. Seats and seat inserts
    c. Doors
    d. Underfloor equipment
    e. Trucks
    f. Windshield wipers
15. Removal, replacement, and adjustment, where applicable, of vehicle electrical equipment, such as the following:
    a. Windshield wiper motor
    b. Heaters
    c. Circuit breakers
    d. Switches and indicators
    e. Light fixtures
16. Rerailing procedures
17. Emergency and rescue towing procedures

19.5 Spare Parts

Furnish the spare parts listed in Contract Documents:

1. Based on the submitted recommended spare parts list; actual items and quantities may be adjusted after Contract award by amendment.
2. Individually package and label vehicle sets of spare parts and consumables with part numbers.
3. Part numbers shall be the same as those indicated in the specified Parts Catalog.
4. Use of SEPTA spare parts for Contractor's warranty support is restricted. If SEPTA approves the use of spare parts for such activities, parts used shall be replaced with new and unused assemblies.

19.6 Technical Support Personnel

Furnish technical support personnel as follows:

1. Field Service Engineer:

   a. Provide sufficient personnel to be able to provide adequate support for work in multiple SEPTA locations and for the listed expertise.

   b. Location: At SEPTA's facilities.

   c. Qualifications: Knowledgeable in each of the vehicle's systems to the level of competent troubleshooting.

   d. Availability: Full time.

   e. Language: Fluent in English.

   f. Availability: Any of three eight-hour shifts, as may be required by SEPTA.

   g. Purpose:

      - Assist during inspection, operation, testing, modification programs, and adjustment of vehicles both before and after Conditional Acceptance by the Engineer.
      - Assist in commissioning, acceptance, and warranty for SEPTA vehicles.
      - Assist in training that may be required, in addition to the training specified above, both before and after Conditional Acceptance by the Engineer.

   h. Time period: Minimum from one month before arrival of the first vehicle through the General Warranty Period of the last vehicle.

2. Suppliers: Ensure that the expert services of equipment suppliers and designers are available, on short notice, during the same period to assist the on-site support personnel in the investigation and resolution of vehicle and equipment malfunctions.

3. Additional on-site technical assistance: If requested by SEPTA, furnish as follows:

   a. Delivery of first vehicle to Final Acceptance of last vehicle: Within 48 hours from receipt of request by the Engineer.

   b. Warranty Period: Within 72 hours from receipt of request.

19.7 Firmware/Software Updates

As firmware and software updates are made to components and systems provided on vehicles, notify SEPTA and furnish those updates to SEPTA for the life of the vehicle:

1. Allow SEPTA adequate time for review and **approval** of software updates prior to their implementation.

2. Document all software updates on a software change log and furnish to SEPTA.

3. All Approved software updates shall have accompanying software release documentation furnished to SEPTA.

4. Furnish firmware and software updates with a detailed field modification instruction that includes all necessary information for SEPTA personnel to maintain these updates.

5. Furnish all on-vehicle and off-vehicle critical and safety related software updates to SEPTA at no cost for the life of the vehicle. Updates shall comply with the requirements specified in Section 18, Systems and Software Engineering.

19.8 Contract Deliverables Requirements List (CDRL)

19-1 Operator's Instruction and Troubleshooting Manual
19-2 Maintenance and Servicing Manual
19-3 Heavy Repair Manual (HRM)
19-4 Component Repair Manual
19-5 Illustrated Parts Catalog
19-6 Training Manuals
19-7 Special Tools and Diagnostic Equipment Manuals
19-8 Integrated Schematic Diagrams for Troubleshooting
19-9 Maintenance Allocation Chart
19-10 Special Tools and Diagnostic Equipment
19-11 Draft Training Plan
19-12 Operator Training DVDs
19-13 Required Spare Parts
19-14 Recommended Spare Parts
19-15 Knowledge Gap Analysis
19-16 Operator’s Vehicle Condition Report

19.9 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance:

19-1 Operator’s Instruction and Troubleshooting Manual:

1. This manual shall contain all information needed for optimum operation of the vehicle.

2. Include general vehicle familiarization material, such as the following:

   a. Description of location, function and operation of controls, gauges, indicators and switches
   b. Discussion of the trucks, couplers, propulsion, brakes, doors, bridge plates, lights, HVAC control, and other features of the vehicle which the Operator may not be able to control or adjust, but of which the Operator should have some basic knowledge
   c. Safe practices and procedures
   d. Emergency procedures
   e. Trouble symptoms and diagnosis methods
   f. Operator corrective action

3. The manual shall be logically organized with systems and elements considered in descending order of importance.

4. Ensure that all statements are clear, positive, and accurate, with no possibility of incorrect implications or inferences.

5. Include copies of the Operator's Vehicle Condition Report specified in CDRL 19-16.

6. This manual shall be durable enough to be able to travel with each Operator from vehicle to vehicle.

7. Size: 5 inches by 7 inches

19-2 Maintenance and Servicing Manual:

1. This manual shall contain all necessary maintenance information for use by SEPTA's maintenance staff for:

    a. Preventive maintenance inspections
    b. On-vehicle running maintenance and adjustment
    c. In-service trouble diagnosis of each system

2. Include safe practices and procedures.

3. Include such data as troubleshooting guides, equipment specifications, and references to the Integrated Schematic Diagrams and Software Functional Description with error code troubleshooting assistance.

4. Include intervals of preventive and required maintenance. List the preventive and required maintenance on a chart that defines the intervals and type of maintenance for the first 10-year period of the vehicle.

5. Include forms required for each type of inspection or required maintenance. Each form shall include tasks to be performed and required parts to be used in the inspection or task.

6. Include a detailed analysis and theory of operation for each component of the vehicle so that maintenance staff can effectively service, inspect, maintain, adjust, troubleshoot, repair, replace, and overhaul each component.

7. Include the list of recommended cleaning agents submitted under Section 16, Materials and Workmanship.

8. Include the maintenance information for paints and coatings submitted under Section 16.

9. Include a detailed explanation of normal vehicle start-up sequence of operation, and guidance for vehicle testing as failures are observed at each step in the sequence.

10. Size: 8-1/2 inches by 11 inches.

19-3 Heavy Repair Manual (HRM):

1. This manual shall contain the maintenance procedures performed at the Heavy Repair level.

2. Heavy Repair Maintenance is maintenance that requires holding a vehicle out of service due to the longer time required to complete the work, and includes maintenance tasks scheduled for 3-year or greater intervals that are associated with vehicle and equipment overhaul.

3. Include information necessary for repairing structural and surface damage due to collision. This shall include necessary vehicle-body data, materials needed for wreck repair, shop practices, and detailed procedures.

4. The opening section of the HRM shall be a table of Heavy Repair tasks, organized by interval, then by subsystem. The table shall refer to subsections of the HRM where procedures for each task may be found.

5. The manual shall be written from a vehicle subsystem and component perspective:

   a. Each subsystem section shall begin by illustrating the location of components within the subsystem.
   b. Functional descriptions shall accompany the illustrations to facilitate servicing, repair, overhaul, adjustment, inspection, and test.
   c. Detail the function of each significant component and circuit within each assembly, rather than furnishing descriptions of subsystem functions within the integrated vehicle system.

6. Furnish maintenance procedures, including inspection, service, test, troubleshooting, adjustment, removal, repair, replacement, and overhaul, as applicable for this specific vehicle or its systems, equipment, or parts.

7. Assembly procedures shall each include pertinent assembly criteria, such as clearances, backlash dimensions, torque values, recommended tools, required supplies, necessary follow-on tasks (if applicable), and similar data.

8. Procedures shall include detailed instructions for troubleshooting all anticipated failure modes, including the use of necessary special tools, PTUs, and Bench Testers.

9. Furnish a listing of all tools required to perform maintenance on the vehicles and apparatus, including both special and commercially available tools.

10. Include safe practices and procedures.

19-4 Component Repair Manual

1. This catalog shall be a compilation of documents for the direct support of the back-shop component-level troubleshooting and repair utilizing associated BTEs, PTUs, and special tools.

2. The component repair manual shall include, at a minimum, the following:

   a. PCB Schematics
   b. PCB Parts Listings if not included in vehicle
   c. BTE Operations Manuals
   d. BTE Test Routine Logic descriptions
   e. BTE and special tools electrical and mechanical drawings
   f. PCB Test Specifications

g. PCB Trace Layouts
h. PCB Component Layouts
i. Test Reports with Pass/Fail criteria
j. OEM Equipment Manuals
k. BTE PC Software Loading Manuals
l. PCB Schematic narratives
m. Software and firmware uploading procedures
n. Unit-under-test (UUT) reference tables
o. BTE Design Description manuals
p. PCB functional block diagrams
q. Unit, Module, and PCB disassembly and assembly procedures.

19-5 Illustrated Parts Catalog:

1. This catalog shall identify each component on the vehicle by part number down to the Lowest Level Replaceable Unit (LLRU). The LLRU is defined as the lowest level of component assembly that consists of a separate, individually fabricated part

2. Enumerate and describe each component with its related parts for the entire vehicle.

3. Incorporate drawings showing exploded views and cutaways of subassemblies and components to permit identification of all parts down to LLRUs.

4. Identify each part with the Contractor's part number and next higher assembly. Include the supplier's part number if different from the Contractor's number.

5. Parts common to different components, such as bolts and nuts, shall bear the same Contractor's number in all components with a reference to the other components in which they are found.

6. In addition to identifying each component by the Contractor's number, identify commercially available items such as common fastenings, fuses, lamps, fittings, bearings, and relays by standard hardware nomenclature adequate to allow SEPTA to purchase these items through commercial channels.

7. Include an appendix that lists each supplier's contact information, including URL, in order to expedite procurement.

8. Size: 8-1/2 inches by 11 inches.

19-6 Training Manuals:

1. This manual shall contain material to aid trainees who receive the required training, as specified in the "Training" section.

2. Manuals and other training materials to be used by the Contractor during training shall be furnished to the Engineer two months before training is conducted.

3. The manuals shall be complete, and contain an adequate supply of high quality, professionally prepared material of professional quality.

4. Include the final training plan, after **approval** of the draft training plan.

5. Size: 8-1/2 inches by 11 inches.

19-7 Special Tools and Diagnostic Equipment Manuals:

1. Submit manuals for each special device identified in the Special Tools and Diagnostic Equipment section.

2. Include setup and testing procedures for each special tool and test device.

3. In a separate section, include all information needed for periodic inspection and servicing requirements of the diagnostic equipment, including lubrication, inspection, and adjustment of all apparatus.

4. Include all drawings of each special tool furnished to SEPTA.

5. Size: 8-1/2 inches by 11 inches.

19-8 Integrated Schematic Diagrams for Troubleshooting:

1. Submit diagrams detailing all electrical, electronic, pneumatic, and hydraulic systems in schematic fashion. These diagrams shall be separate from the schematics, piping diagrams, and wiring diagrams in the maintenance manuals.

2. These schematics shall be comprehensive, thoroughly detailed, include all components, and include the following:

   a. Electrical systems
   b. Electronic systems
   c. Firmware logic schematics
   d. Pneumatic systems
   e. Hydraulic systems
   f. Refrigerant
   g. Wiring
   h. Piping

3. Diagrams shall reflect SEPTA's vehicle as-built, and include all circuits on the vehicle.

4. At a minimum, include the following on the schematics:

   a. Zone gradations around the perimeter of each sheet for location references.
   b. Alpha-numeric designations for all components. The designations shall be logical and clearly distinguish between different component types, such as CBxxx for circuit breakers.
   c. All contacts or connections for relays, contactors, connectors, and other devices with multiple contacts or connections, even if unused.
   d. Numerical designations for all circuit wiring, with logical groupings for power sources, return circuits, and similar.
   e. Wire sizes and circuit voltages, piping sizes and system pressures, and similar.
   f. Industry standard device symbols and nomenclature for piping, hydraulic, and pneumatics diagrams, such as defined by ANSI or similar organizations.

g. Signal names for all levels of schematics from vehicle level to circuit board level shall be consistently applied for fault tracing.

5. Number pages numerically and consecutively.

6. In addition to the required quantity of hard copies, submit two copies in an electronic format that is readable and searchable on a PTU screen and formatted to print on 11 inch x 17 inch paper.

7. Hard Copy Size: 11 inches by 17 inches.

19-9 Maintenance Allocation Chart:

1. Submit a guide for use by SEPTA to determine vehicle maintenance and repair time.

2. Include standard times and schedules for recommended preventive maintenance tasks.

3. Include standard repair times, replacement times, and scheduling for all major components and the associated sub-assemblies.

19-10 Special Tools and Diagnostic Equipment

19-11 Draft Training Plan:

1. Include information detailing the types of training and the number of hours required to train SEPTA's staff.

19-12 Operator Training on USB storage devices:

1. Submit two copies.

2. Submit the USB storage devices minimum 30 days before delivery of the first vehicle.

3. Video training shall include the following:

   a. Preparing a vehicle for service
   b. Operating a vehicle under normal conditions
   c. Emergency procedures for moving a vehicle under fault conditions

19-13 Required Spare Parts:

1. For components that are listed in the Contract as required spare parts but are not applicable to the Contractor's specific design, indicate "not required."

2. Include part numbers.

3. Include dimensions and weight information of spare parts for SEPTA supply chain management.

19-14 Recommended Spare Parts:

1. Include spare parts recommended by the Contractor that are in addition to those specified.

2. Include part numbers.

19-15 Knowledge Gap Analysis:

1. Include an analysis of necessary knowledge for Operators and maintenance personnel that is not included on the existing LRVs.
2. Include recommended technology primers for Operators and maintenance personnel.

19-16 Operator's Vehicle Condition Report:

1. Include a form for Operators to report vehicle defects to the Contractor.

19.10 Training Simulators

Provide two (2) training simulators according to the requirements of Appendix [E, Training Simulators].

19.11 Referenced Standards

The following standards are referenced in this Section:

APTA PR-IM-RP-002-98	Passenger Rail Equipment Technical Documentation
APTA-RT-RMT-RP-001-10	Rail Vehicle Maintenance Training Standards

END OF SECTION

Table of Contents

20.1 General

Control the design and production of vehicles to ensure a high-quality product suitable for long and trouble-free life and ensure that requirements of the Specifications are met.

SEPTA shalll, at its option, monitor Contractor activities regarding this Contract, including subcontractor activities, and inspect and test equipment. The Contractor shall not hinder or limit such activities.

20.2 Program Management

20.2.1 Project Management

Designate a project manager and submit a Project Management Plan, including an organization chart, workflow diagram, and program schedule with Gantt chart, as specified below. See the CDRL Detail section, below for CDRL details.

20.2.1.1 Project Management Organization Chart

Develop and submit a project management organization chart for the Contractor’s staff:

1. Include a list of dedicated personnel responsible for internal reporting on manufacturing milestones as part of the SEPTA Contract, and key subcontractor personnel.

2. Indicate management personnel responsibilities in relation to engineering, manufacturing, QC, material procurement and other supporting functions.

20.2.1.2 Workflow Diagram

Develop and submit a workflow diagram:

1. Clearly depict the design, manufacturing, testing, and inspection workflow, including Hold and Witness inspections.

2. Indicate responsibilities of the Contractor and each subcontractor or supplier for all systems and major components described in the Specifications.

3. Information furnished shall be consistent with, and expand upon, the Contractor's Proposal or BAFO that is incorporated into the Contract Documents.

4. This Workflow Diagram and any changes to it, shall be submitted to SEPTA for review and **approval**. This diagram will be integrated into the Project Management controlled Document package as part of the Contract.

20.2.1.3 Program Schedule

Develop and submit a Critical Path Method (CPM) schedule:

1. Indicate the reasonability of achieving the milestone dates, including the specified vehicle delivery schedule.

2. Include a Gantt chart.

3. Include the following activities as a minimum:

   a. Submittal of general arrangement drawings

   b. Each major system subcontractor under contract

   c. Type Test of each major system and component

   d. First Article Inspection of each major system and component

   e. Key design activities, including design completion dates, for both Contractor and major system subcontractors

   f. Anticipated date of each Preliminary Design Review and Final Design Review for all major systems, as mutually agreed by the Engineer and the Contractor.

   g. Commencement of Pilot Vehicle and Production Vehicle No. 1 parts manufacture

   h. Commencement of Pilot Vehicle and Production Vehicle No. 1 subassemblies manufacture

   i. Commencement of Pilot Vehicle and Production Vehicle No. 1 major assemblies manufacture

   j. Completion of Pilot Vehicle and Production Vehicle Shell No. 1

   k. Vehicle Shell No. 1 static load test

   l. Commencement of truck manufacture (each type, if more than one type)

   m. Completion of first truck (each type, if more than one type)

   n. Truck static load test(s)

   o. Truck fatigue test(s)

   p. Completion of the Pilot Vehicle and Production Vehicle No. 1 at the Contractor's plant

   q. Functional testing of the Pilot Vehicle and Production Vehicle No.1 (Pre-shipment)

   r. Watertightness Testing (if not considered in Functional Testing of each vehicle)

   s. First Article Inspection of Pilot Vehicle and Production Vehicle No.1

   t. Shipment of Pilot Vehicle and Production Vehicle No.1

   u. Arrival, testing of each vehicle (both Type Testing and Routine Testing)

   v. Burn-In Test of each vehicle

   w. Commissioning test of each vehicle

   x. Anticipated or projected Conditional Acceptance of each vehicle

4. As part of the schedule, furnish a schedule narrative, describing the overall approach to meeting required milestones:

    a. Follow and describe the CPM schedule activities to the extent practical
    b. Address each of the following:

        - Rationale for the given activity durations
        - Rationale for the given activity interconnecting logic
        - Possible work-arounds in the event of delay
        - Identification of areas where delay is most likely, and the mitigation efforts planned to reduce the risk of delay.

20.2.2 Monthly Progress

Track actual progress of the work and submit a monthly report:

1. Summarize work accomplished during the month against FTA Quality Management System Guidelines 2019

2. Include work in progress and work planned for the following month.

3. Include a discussion of the Project schedule status. If the Project Schedule is amended, include amended dates for prior scheduled work with mitigations to reduce delay.

4. Include quality activities, with the following as a minimum:

    a. FAI schedule and status

    b. Inspection and test status

    c. Changes issued and their status

5. See the CDRL Detail section, below, for CDRL details.

20.2.3 Document Management

Comply with the following:

1. Identify correspondence and Contract deliverables according to an **approved** coding scheme:

    a. Correspondence and Contract deliverables shall be numbered separately. Revisions of deliverables shall be tracked and reported as part of the document management process.

    b. Propose a scheme suitable for the anticipated quantity of correspondence and Contract deliverables.

    c. If any CDRL will be submitted in more than one part, include a scheme for identifying each part of a CDRL package such that each part has a unique identifier and it is clear that all parts belong to the same CDRL package.

    d. See the CDRL Detail section, below, for details of the Correspondence and Contract Deliverable Coding Scheme CDRL.

2. Furnish a consolidated listing of all CDRLs required by the Specifications. See the CDRL Detail section, below, for details of the CDRL Report.

3. Drawing and Document Status:

   a. Maintain a continuous record of Contractor and subcontractor drawing and document status and submit monthly. This record shall include revision history with dates of change, review and SEPTA **approval**.

   b. Retain copies of all records and make them available to SEPTA for a minimum of 10 years after expiration of all warranty periods, unless otherwise specified.

   c. See the CDRL Detail section, below, for details of the Contract Deliverables Status Report.

20.2.4 Project Meetings

20.2.4.1 General

Hold meetings between the Contractor and the Engineer on a regular basis for the purpose of reviewing program progress and other program activities that cannot be readily resolved by correspondence.

Ensure that persons knowledgeable in the topics to be discussed, including subcontractors, are present or available by teleconference at all meetings.

20.2.4.2 Meeting Minutes

Take minutes for each project meeting:

1. Prepare and submit after each meeting. Designate a dedicated individual/process with responsibility for recording minutes of each project meeting.

2. Include an Action Items List with space for projected closure dates for each action item.

3. See the CDRL Detail section, below, for detailed requirements. The level of detail will be evaluated by the Engineer after the first submittal.

4. Once **approved**, use the same format and level of detail for each subsequent report.

5. Confirm meeting minutes before closure of each meeting to ensure agreement on language and content.

6. The Engineer will Approve the minutes or request revisions within 10 days of receipt of the minutes, or else the minutes shall be considered **approved**.

20.3 Design Progression

20.3.1 Specification Review

Within 30 calendar days after NTP, conduct a Specification Review Meeting. During this meeting the Contractor's Project Manager and technical specialists, major subcontractors and suppliers, and the

Engineer will populate the Specification Compliance Matrix (SCM) specified in the Contract Deliverables Requirements List (CDRL) section, below.

1. Use the SCM to document the Contractor's compliance with each Specification requirement in spreadsheet format.

2. Update the SCM on a regular basis and submit monthly, as specified in the CDRL Detail section, below.

20.3.2 Safety Management System Plan

Review SEPTA's Safety Management System Plan for compliance within each section of the Specifications.

20.3.3 Vehicle Conceptual Design Definition

At the start of the design review phase, conduct working sessions with the Engineer on the layout and concept of the Vehicle. Submit a System Functional Description (SFD) and Individual Systems SFDs, as specified in Section 17, Controls, Networks, and MDS.

20.3.4 Design Review

20.3.4.1 Design Review Meetings

Conduct a design review meeting for each major system for preliminary, in-process, and final design reviews:

1. Major Systems: As defined in the Commercial Provisions. All major system reviews shall include associated support system details.

2. Submittal Package: 30 days prior to each design review meeting, submit a design review package containing design drawings, SFD, and supplemental information appropriate for the type of meeting.

3. The Engineer's Review: After review of the submitted design review package, the Engineer will transmit comments and questions:

    a. The Engineer's comments and questions will form the basis for the design review meeting agenda.

    b. Additional review comments may be communicated by the Engineer at the design review meeting and with transmittal of the design review meeting minutes.

4. Meeting Location: As mutually agreed, including sites of the vehicle manufacturer and any of its subcontractors or suppliers.

5. Meeting attendees: Representatives of the Contractor; appropriate subcontractors and suppliers; and the Engineer or his or her representative, or both.

6. Meeting Minutes: Will be reviewed before closing the meeting.

7. First design review meeting in each phase shall cover the overall system design as described in the SFD.

8. The Engineer may request working sessions at any point in the design progression at mutually agreed times.

20.3.4.2 Conceptual Design Review (CDR)

The purpose of the CDR phase is for the Contractor to seek early agreement on the approach to the design of the vehicle and its systems.

1. The designs proposed during the CDR phase shall be based on and consistent with the Specifications, shall provide sufficient information to fully describe the design approach and any alternatives that may be available, and shall detail the performance of each subsystem relative to the Specification requirements.

2. The CDR phase shall be implemented progressively on a system-by-system basis.

3. Include subcontractor participation at each CDR phase design review meeting.

4. Detailed content of design review packages submitted for the CDR phase milestone design review shall describe the work completed during this phase of the Contract.

5. Prepare and present a final package of all required and **approved** contract deliverables (drawings, analyses, calculations, samples, test reports, and similar) at the conclusion of the CDR phase as validation for progression into the Preliminary Design Review phase.

20.3.4.3 Preliminary Design Review (PDR)

Demonstrate in the PDR that the preliminary design meets all system requirements with acceptable risk and within the schedule constraints, and establish the basis for proceeding with detailed design. Implement Risk Mitigations as required when process deviations occur.

Show the following as a minimum:

1. All system requirements have been allocated and the requirements are complete.

2. The proposed design is expected to meet the specified functional and performance requirements.

3. The proposed design approach is ready to proceed to final design.

4. Interfaces have been identified.

5. The design is verifiable, and risks have been identified, characterized, and mitigated where appropriate.

20.3.4.4 In-Process Design Review (IPDR)

If the Engineer determines that IPDRs for specific systems are necessary, demonstrate that design is progressing as expected by the Engineer, based on the PDR.

20.3.4.5 Final Design Review (FDR)

Demonstrate in the FDR that the design is essentially complete and ready for production of first article inspection units. Resolve all PDR and IPDR issues before scheduling FDR activities.

Show the following as a minimum:

1. The final design fulfills the requirements established at PDR.
2. The production processes and controls are sufficient to proceed to the manufacturing stage.
3. Planned Quality Assurance (QA) activities are sufficient to produce a quality product, and have been submitted for review and disposition.

20.3.5 Pilot Vehicle Program

20.3.5.1 General

Provide one pilot vehicle for the City Division and one pilot vehicle for the Suburban Division.

Purposes of the Pilot Vehicle Program include the following:

1. Initiate the debugging, systems integration testing, and proof-of-design testing on the new vehicles.
2. Ensure that acceptable design configuration and vehicle performance are achieved, and all interface and electrical interference issues are addressed before vehicles are in full production.
3. Minimize the risk of potential delays between delivery of the Pilot Vehicle and production vehicles.
4. Decrease the chance of costly and inconvenient retrofits.
5. Familiarize SEPTA Operations and Maintenance personnel with the vehicles.

20.3.5.2 Vehicle Baseline

The Pilot Vehicles shall be used to determine the baseline of all system performance and quality, subject to **approval**.

1. After completing Pilot Vehicle testing, the Contractor and SEPTA shall meet to review the Configuration Status Report to identify portions of the Specifications, **approved** drawings, and test procedures requiring change to establish the baseline for the vehicle.
2. Once the baseline has been set and **approved**, all changes to the baseline shall be documented by a change to the controlling document that reflects the baseline requirement in the form of drawings, procedures, or software revision levels.
3. The Pilot Vehicle shall be considered a "proof of design" first article after being exercised in test and revenue service, and the adequacy of all aspects of the design and manufacturing activities have been substantiated.

4. During the test period for the Pilot Vehicle, the Contractor may continue work on other vehicles at its own risk, but no additional vehicles may be shipped to SEPTA until **approval** of the Pilot Vehicle for production release.

5. Delivery of production vehicles shall not commence until the Pilot Vehicle Program has been completed and proof that any adjustments or changes found necessary during the Pilot Vehicle Program are properly documented and incorporated into the production vehicle configuration.

6. SEPTA reserves the right to disallow shipment authorizations, thus restricting delivery, until all Pilot Vehicle Program items have been either closed or dispositioned as **approved**.

20.3.5.3 Design Development

The Pilot Vehicles shall comply with the following:

1. Vehicles shall be assembled based on the drawings previously **approved** during the design phases, and the assembly drawings submitted for evaluation.

2. Construction shall not begin until all supplier certifications have been obtained and **approved**.

3. Pilot Vehicles shall precede all other vehicles in all stages of production.

4. Assembly of a full vehicle shall not commence until the structural shell has been provisionally **approved**.

5. Pilot Vehicles shall be assembled with all systems and equipment installed, properly integrated, and fully functional.

6. Vehicle assembly drawings shall go through an evaluation process during the Pilot Vehicle assembly phase.

7. It is the responsibility of the Contractor to ensure that details contained within the drawings meet the requirements of the Specifications.

8. Furnish all mock-ups prior to the production of the Pilot Vehicles. Mock-ups shall be kept at complete, current status and updated as necessary based on design review comments until the Pilot Vehicle is completed.

9. Perform all engineering changes approved as part of the Pilot Vehicle Program on all vehicles unless **approval** is given to incorporate at an effective point later than the first vehicle. This is not intended to discourage the incorporation of approved design improvements as "effective point" changes during construction.

20.3.5.4 Pilot Vehicle Assembly

Comply with the following:

1. Treat the Pilot Vehicle shells as a singular major component with its own design review, assembly evaluation, and testing. General assembly of a full vehicle shall not commence until the structural shell has been Conditionally **approved**.

2. Installation of all major systems, subsystem components, and equipment shall have an **approved** FAI status prior to installation.

    a. Take special care in the evaluation of the installation and mounting of such system equipment.

    b. The subcontractors and suppliers shall be responsible for the certification of installation and integration during this period and prior to the Pilot Vehicle FAIs.

3. The Engineer reserves the right to examine and **approve** each assembled and completed part of the work before it is concealed, or similar work is undertaken on production vehicles.

    a. This procedure shall be continued until the Pilot Vehicle is complete and ready for delivery.

    b. All production vehicles shall be completed in accordance with the Pilot Vehicle, and no changes shall be made unless **approved**.

    c. During the assembly of the Pilot Vehicle, the Engineer will monitor the build process to evaluate the effectiveness of the configuration and compliance to the requirements of Section 16, Materials and Workmanship.

4. Drawings used in shop work areas shall be compared to the master list of approved design drawings to ensure the same versions are used to manufacture and inspect the work.

5. Notify the Engineer of other stages of manufacture that are of importance or benefit to the Engineer in evaluating the work.

    a. These stages will be attended at the discretion of the Engineer.

    b. Give minimum seven days' notice for each of the listed stages of completion.

    c. Additional inspections of the Pilot Vehicle may be performed by the Engineer during construction of the Pilot Vehicle. The Engineer will advise the Contractor of **approval** or required corrections required at the time of the inspection.

6. Scheduled hold point Inspections of the Pilot Vehicle will be made at the following stages of the work, which are not necessarily in the sequence of completion. Final list of hold-point inspections, including the following, shall be **approved**:

    a. All underfloor equipment, piping, and wiring installed and connected

    b. Major structural assemblies and complete vehicle body without insulation

    c. Water test of the vehicle-body structure

    d. Vehicle-body structure complete without linings

    e. Side doors installed and operating without side linings

    f. Air conditioning apparatus and ducts in place and connected without linings

    g. Cab complete

h. Linings installed without seats including equipment compartments, electric lockers, and lighting
i. Vehicle complete in all respects, ready to run
j. All systems shall be operating during inspection
k. Truck fitted with all propulsion equipment
l. Complete propulsion system installed

7. Document discrepancies found during assembly in the Configuration Status Report, investigate to determine root cause, and take appropriate action to correct the problem. Issues discovered shall be identified as either quality or engineering related.
   a. Engineering issues shall be defined as items in need of change due to fit, form, function, materials, circuitry, or software changes where the configuration of the vehicle will change as shown in drawings, schematics, or software revision levels.
   b. Quality issues shall be tracked and monitored, investigated for root cause, and quickly corrected during the assembly phase.

20.3.5.5 Pilot Vehicle First Article Inspection

Conduct First Article Inspections (FAIs) for the Pilot Vehicle per the requirements of the First Article Inspections (FAI) section, below.

1. FAIs shall evaluate and verify component and system function, accessibility, and maintainability where possible. Each FAI shall include a maintainability demonstration. This process shall include verification of draft maintenance and training manual instructions.
2. FAI's shall be performed on components built by qualified production workers using **approved** designs, production processes, and tooling, and shall establish the standard of quality of workmanship for the balance of like components.
3. FAIs shall not be conducted until the design drawings of the article have been Conditionally **approved** or **approved**.
   a. If Conditionally **approved** drawings are used, the conditions for **approval** shall be satisfied at the FAI and represented by the inspection article.
   b. FAI shall verify dimensions and workmanship according to **approved** drawings and workmanship acceptance standards. Product examples, color photographs, or both may be used to enhance recognition of acceptable and unacceptable conditions.
4. Routine tests shall be performed in conjunction with the FAI, when practical.
5. Successful completion of this FAI process will result in provisional **approval** of the vehicle's design and assembly level drawings pending any further changes due to post-delivery Pilot Vehicle proof-of-design testing.

20.3.5.6 Pilot Vehicle Pre-shipment Inspection and Tests

Comply with the following:

1. Conduct inspections per the Quality Control and Inspection Plan (QCIP) section, below.
2. Ensure that the following tests specified in Section 15, Testing, have been successfully completed and that test reports have been **approved** prior to conducting Vehicle Level Type Tests at the Contractor's Facility, as specified in Section 15:
    a. Component Type Tests
    b. Vehicle Shell Structural Type Tests
    c. System Type Tests
3. During assembly, perform pretests similar to the following tests specified in Section 15, prior to the Pilot Vehicle FAIs:
    a. Component Routine Tests
    b. Vehicle-Level Routine Tests at the Contractor's Facilities
4. Changes resulting from testing such as circuit changes, software, or test procedural changes shall be documented in the Configuration Status Report.
5. Changes shall be made prior to the official FAI production testing to allow confirmation of the changes' effectiveness.

20.3.5.7 Pilot Vehicle On-site Tests

Comply with the following:

1. Upon arrival of the Pilot Vehicle at the designated SEPTA facility, visually inspect for shipping damage.
2. After visual inspections and adjustments and repairs have been completed, conduct the following on-site tests specified in Section 15, Testing:
    a. Vehicle-Level Routine Tests at SEPTA's Facilities
    b. Vehicle-Level Dynamic Type Tests at SEPTA's Facilities
3. After completion of routine and dynamic tests at SEPTA’s facilities, conduct simulated revenue service tests similar to the Burn-in Test specified in Section 15.
    a. The vehicle shall be instrumented during these tests to verify that all systems are functioning properly.
    b. With **approval**, the vehicle diagnostic system may be used instead of instrumentation, if it can provide sufficient information to evaluate and document test results.

c. Tests shall be conducted more than 160 km (100 miles) of simulated passenger service on Route 36, under the following conditions:

- AW3 load
- Stopping at every station and cycling the doors
- Bridge plates cycled every 10 station stops

d. During the test, there must be no failures of equipment. If a failure occurs, the test shall be repeated following correction and documentation of the failure.

20.3.5.8 Configuration Upgrades

Comply with the following:

1. At the completion of Pilot Vehicle testing and upon the Engineer's direction, return the Pilot Vehicle to a Contractor facility for configuration upgrades. Pilot Vehicle configuration upgrades on SEPTA property are prohibited.

2. The Contractor is responsible for all costs associated with the return transportation of the Pilot Vehicle to the Contractor's facility, and final Delivery to SEPTA upon completion of configuration upgrades.

3. Production and Delivery of production vehicles may continue while Pilot Vehicle configuration upgrades take place at the Contractor's facility.

20.3.5.9 Pilot Vehicle Configuration Control

Throughout the Pilot Vehicle Program, the Contractor and SEPTA shall jointly develop and maintain a Configuration Status Report:

1. The report shall be shared with both the Contractor and the Engineer upon any changes or updates.

   a. The Configuration Status Report is intended to be a working document between SEPTA and the Contractor to track corrective action of issues to the configuration of the vehicle design found during the assembly, inspection, and testing of the Pilot Vehicle.

   b. Corrective actions that result in the change of controlled documents (drawings, test procedures, etc.) shall be fully documented in the report.

2. During the assembly, inspection, and testing of the Pilot Vehicle, document in the report perceived discrepancies to the vehicle's configuration in regard to requirements of the Specifications or **approved** design phase documentation. Record drawing deficiencies and objections in the report and correct prior to testing.

3. The report shall include the following:

   a. Problems with equipment interface or tolerances found during inspection, audits, or supplemental drawing reviews.

   b. Proposed corrective action to be filled in during change discussions with the Contractor.

   c. A field for the governing drawing or document at the time that the discrepancy was identified, including revision level and an associated field denoting document change status and revisions at the time of closure.

4. Changes to the associated documents and to the vehicle shall be jointly verified upon completion.

5. It is intended that, except where otherwise approved or required by the Engineer, the Pilot Vehicle's manufacturing quality level shall be the standard for all following vehicles.

   a. Each following unit shall be an exact counterpart of the Pilot Vehicle in every material and design respect.

   b. If the Engineer discovers a material or design deviation from an approved Pilot Vehicle's configuration in the succeeding production units, the Contractor, unless otherwise **approved**, shall correct such deviation in all affected production units at no additional cost to SEPTA.

6. Add nonconformance issues to the report that affect production baseline drawings by related drawing number and revision for disposition.

   a. Assist the Engineer in identifying any and all applicable drawings that must be changed to resolve such comments, and expeditiously work with the Engineer to identify corrective action.

   b. Revise drawings accordingly prior to each Pilot Vehicle FAI.

7. Changes to drawings during the Pilot Vehicle assembly phase shall be controlled via the Configuration Status Report until the production baseline has been **approved** formally or provisionally. Any and all changes that result in a drawing change after the baseline has been set must be submitted for **approval**.

20.4 Documentation and approval

20.4.1 Submittal of Contract Deliverables

20.4.1.1 Format

Submit Contract deliverables [electronically] as follows:

1. Hardcopy: Four copies. All copies need to be issued via controlled document transmittal process for editing and re-issue purpose.

2. Electronic copy:

   a. Documents and drawings shall be PDFs converted directly from the original word processing and CAD vector formats, such that full zooming is possible without a loss of resolution, and text searching is possible. Individual masters of CAD drawings and spreadsheets may be requested at any time by SEPTA.

   b. Furnish documents and drawings with electronic signatures.

   c. Final documents shall be in editable form, such as in Microsoft Word®, latest version.

d. Submit final drawings in an editable form that is fully compatible with AutoCAD® and/or SOLIDWORKS, latest version.

e. Submit models of parts in SOLIDWORKS pack and go, STEP file, or SOLIDWORKS compatible format.

f. Submit process that outlines Contract Deliverables Document and **approval**.

20.4.1.2 Document Management

Letter of Transmittal:

1. Furnish with submittal of Contract deliverables.
2. List drawing and document titles, numbers, and revisions.
3. If more than one drawing or document is submitted at a time, list the drawings and documents in the transmittal in numerical sequence.
4. Submit process that outlines Document Management for Letters of Transmittal.

Attachment Identification:

1. On each attachment to the letter of transmittal (e.g. CDRLs, drawings, documents, data), furnish an identification reference including the following information:
   a. Letter of transmittal number.
   b. Letter of transmittal date.
2. For drawing packages, or other multiple-sheet attachments, furnish the identification reference on the cover sheet.

20.4.1.3 CDRL Packages

Comply with the following:

1. In general, each CDRL package shall be submitted complete, as described in the Contract Deliverables Requirements List (CDRL) section at the end of each Specification Section.
   a. If part of the CDRL package is not included (permissible only if the submitted parts do not depend on the omitted parts), as a minimum include a complete list of the composition of the complete CDRL package.
   b. If a CDRL package is submitted in more than one part, each part shall include the following:
      - A number that includes the primary CDRL package number and an identifier showing that it is only part of that CDRL package, in accordance with the **approved** Correspondence and Contract Deliverable Coding Scheme.
      - A list of previously submitted parts of the CDRL package with the letter of transmittal number and date of each.

c. If the CDRL package does not include all parts required for the Engineer's review, it may be returned without review and will not be considered as submitted.

d. CDRL Submittal Tracking and SEPTA acceptance of CDRLs shall be reported and managed by the Contractor.

e. Submit process that outlines CDRL Package Submittal Tracking.

20.4.1.4 Drawings

Comply with the following:

1. Submit drawings in an orderly and logical sequence to enable the Engineer to readily determine and review the interface relationships between all major structural elements and their subassemblies, and between the structural elements and the attached apparatus, equipment, wiring, piping, and hardware.
2. Submit a drawing tree showing hierarchy and numbering topology.
3. When submitting drawings of structural parts or assemblies for the vehicle-body structure, equipment supports, and trucks, also submit stress analyses for these parts or assemblies in summary form.
4. Schematics shall include the level of detail to fully and clearly understand the information presented and shall comply with the following:
    a. Components and wiring locations shall reflect the physical vehicle arrangement. For example, show components and wiring on one page, with the wire transitions across articulations clearly indicated.
    b. Components shall be oriented vertically.
    c. Relay coils shall be shown with the complete set of contacts and their connections, even if contacts are not located on that page.
    d. Show one function per page, such as cab control, emergency braking, etc., except as **approved**.
5. Submit subassembly drawings for information to facilitate the review of assembly and installation drawings.

20.4.1.5 Additional Submittals

The Engineer reserves the right to request additional drawings and other data to support the review of assembly and installation drawings, or when needed to understand the Contractor's design.

20.4.2 The Engineer's Review

The Engineer will review and return Contract deliverables as follows:

1. Within 30 calendar days after receipt by the Engineer, with the following exceptions:
    a. Due to the Engineer's limited resources, and to prevent grouping of drawings into one large package for transmittal, the Engineer will not be obligated to review more than 50 drawings, or other mutually agreeable number, in a 30-day period.
    b. If more than 50 drawings are submitted for review in a 30-day period, the Engineer will review them in accordance with priorities as mutually agreed to between the Contractor and the Engineer.
2. The Engineer will respond to the Contractor as per the process outlined in the CDRL Package Submittal Tracking.
3. **Approval** or disapproval will be furnished in one of the four following categories:
    a. **Approved** as Submitted
    b. Conditionally **approved**: The Contractor may proceed in accordance with changes indicated but shall revise and resubmit the document, drawing, or data for **approval**
    c. Disapproved: The Contractor shall revise and resubmit the document, drawing, or data for **approval** before beginning that portion of the work
    d. Accepted for Information Only: The information was submitted to assist in review of a required submittal or to satisfy a request. Specific **approval** and comment not required.

Limitations of **approval**:

1. **Approval** does not relieve the Contractor of the obligation to meet all of the requirements of the Contract.
2. **Approval** of Contract deliverables that contain deviations from, or violation of the Specifications does not constitute **approval** of that deviation or violation. Deviations shall be specifically submitted for **approval**.
3. **Approval** is intended to mean that the Engineer is aware of the Contractor's intent and there are no objections to the apparent methods, procedures, designs, or calculations expressed in the submitted drawings or documents. It does not imply that all calculations, dimensions, materials, components, or other details were checked and verified.

20.4.3 Contractor's Resubmittals

No extension of Contract time will be allowed for revision of Contract deliverables that have been either "Disapproved" or "Conditionally **approved**."

1. Such Contract deliverables shall be resubmitted and will be reviewed and returned to the Contractor within the same time intervals as would be allotted to the Contract deliverables when initially submitted.

2. Resubmitted drawings shall accrue toward the 50 drawings per month limit.

20.4.4 Contract Deliverable approval and Procurement of Materials

Allow adequate time for review and discussion of designs in the procurement schedule.

1. Procurement of materials before **approval** of Contract deliverables is at the Contractor's risk and the material shall be identified as not approved for use.

2. Contract deliverable schedules shall be timely and consistent with the Contractor's procurement schedules.

20.4.5 Requirements for Drawings, Documents, and Data

20.4.5.1 General

Design documents defining vehicle construction shall be complete with regard to dimensions, tolerances, material properties, fabrication methods, and finishing. These documents shall reference all applicable industry standards that apply as part of the production process.

1. Design documents shall be reviewed and approved by the Contractor's QA and production departments before submittal to the Engineer.

2. Where construction drawings are created for production purposes, all details of the design documents shall be included in the construction drawings.

20.4.5.2 Format

Comply with the following:

1. Drawings and forms (e.g., ECR, NCR) shall be in an **approved** format.

2. Drawings shall include the following:

    a. Title block

    b. Drawing number

    c. Title

    d. Date

    e. Revision number

    f. Contract number

    g. Reference to next higher assembly

    h. Signature of the Contractor's responsible engineer

3. Dimensions shall be expressed in the SI system and U.S. customary units (USC):

    a. For dimensions less than 10 m, SI units shall be millimeters. For dimensions 10 m and greater, meters may be used, but millimeters are acceptable.

   b. For dimensions less than 30 ft, USC units shall be decimal inches. For dimensions 30 ft and greater, decimal feet may be used, but decimal inches are acceptable. Fractions are prohibited.

4. Revision block: Include for documents, drawings, and data:

   a. Identify the revision letter and date of revision

   b. Include initials of the Contractor's responsible engineer authorizing the revision

   c. Include a description of the change, and the reason for making the change.

5. Wiring diagrams: Format as both integrated connection diagrams and a wire list in book form ("From/To" list) based on the Integrated Schematic (see Section 19, System Support, for requirements regarding the Integrated Schematic Diagrams).

6. Hydraulic piping diagram: Format as both integrated connection diagrams and a pipe list in book form ("From/To" list) based on the Integrated Schematic (see Section 19, System Support, for requirements regarding the Integrated Schematic Diagrams).

7. HVAC Air Circulation feed: Include pneumatic diagrams of HVAC air circulation feed and return air-flow in-vehicle.

20.4.5.3 Content

The content for electrical drawings and schematics should be supplied for each system and all lower-level units and modules. Comply with the following:

1. For drawings, especially those showing structural members and outside sheathing, indicate material type and dimensions.

2. Assembly drawings: Include a bill of material.

3. Integrated connection diagrams (electric and hydraulic): Indicate all wiring, piping raceways, conduits, and connections.

4. Electrical drawings and schematics: As a minimum, provide the following information for each wire segment:

   a. Wire code (schematic designation)

   b. Origin (FROM device and terminal)

   c. Destination (TO device and terminal)

   d. Wire size

   e. Voltage rating

   f. Length

   g. Appropriate specifications

   h. Jacket color

i. Harness designation

20.4.5.4 Standards

Contractor and subcontractor drawings shall conform to the following standards:

1. ASME Y14.38, Abbreviations and Acronyms for Use on Drawings and Related Documents.
2. IEC 60617 (database) or NEMA ICS 19.
3. Other recognized industry standards, as proposed by Contractor and **approved**.

20.4.5.5 Final Drawings

See the CDRL Detail section, below, for requirements of the complete list of final drawings, and for final drawings of the as-built condition of the vehicle.

Include the following in final drawings:

1. Contractor's and subcontractors' drawings, details, bills of material, and catalog cuts that are required by SEPTA for future installation, maintenance, repair and overhaul purposes.
2. Assemblies, subassemblies, and arrangements of the vehicle as finally furnished, modified, and accepted.
3. Electrical schematics, electronic circuits, and wiring diagrams. Verify the schematics provide information faults, alarms, error messages that each system is capable of reporting related to vehicle operation and maintenance.
4. Hydraulic schematics, hydraulic circuits, and piping diagrams.
5. Interface control drawings down to the LLRU.
6. Items that are special purpose or fabricated by the Contractor.
7. Materials furnished by the Contractor and by its subcontractors, down to and including the module and circuit board level. Outline drawings are not considered acceptable.
8. HVAC air flow diagram with illustrations for feed and return of in-vehicle air and where air sanitizing systems/filters are located.

20.4.5.5.1 Document Index

For groups of documents (like SOLIDWORKS drawings) the Contractor shall supply an index containing:

a. Document Number

b. File name

c. Any alternate numbers (like manufacturer's part numbers).

d. Document Revision

e. Title

f. Native document size (like A, B, A4, A0)

g. Total sheets

h. Document supplier/manufacturer

20.4.6 Modification and Configuration Control

20.4.6.1 General

Develop modification and configuration control plans and procedures. Throughout the Contract, implement and maintain the configuration control system. See the CDRL Detail section, below, for details of modification and configuration control CDRL.

20.4.6.2 Design Changes

After documents, drawings, and data are **approved**, changes shall be controlled by processing engineering change requests (ECRs) as follows:

1. Submit proposed standard forms and a procedure or the design change process.

2. The process shall include submittal of relevant changes for **approval** prior to implementation.

3. Implementation of a change shall require incorporation into all vehicles, unless otherwise **approved**, and shall require inspection and **approval**.

4. Maintain an Engineering Change Status Report:

    a. List all ECRs, their submittal/**approval** status, status of implementation, which vehicle or part is affected, parts requiring retrofit including serial numbers, projected completion dates and completion dates.

    b. Include the Engineering Change Status Report with the Monthly Progress Report.

20.4.6.3 Component Identification and Serial Numbers

Permanently identify all equipment with a supplier's name, part number, and revision level:

1. Use an **approved** coding system compatible with existing system to identify all LRUs, LLRUs and other replaceable components on the vehicles, all PTUs and BTEs, gauges, special tools and spare parts.

    a. The data for each part shall be as **approved** and shall include at least the following:

        - Manufacturer
        - Model number
        - Part number
        - Serial number

- Date of manufacture
- Contractor's part number
- SEPTA Class/Lot Number
- Drawing number and revision

b. Furnish five **approved** hand-held scanners to be used by maintenance personnel to record maintenance activity, transfer such maintenance data to the configuration/maintenance control system, and to access the electronic manuals for the part/device.

c. Furnish two network-ready printers and associated label material and software to create automatic part and device identification labels. Paper labels shall not be used.

d. The information shall be able to be viewed using a standard phone app.

20.4.6.4 Serialization

Furnish a serialization plan, by system, indicating those items to be serialized, the location of the serial number tag (or engraving), and the method of revision control.

1. If a separate tag is required for configuration control, this requirement shall be addressed in the plan.
2. Serial numbers and configuration numbers, including revision level, (if used) shall be furnished to the Engineer in an **approved** electronic format.

Provide one additional field of 11 characters to accommodate the SEPTA Class/Lot numbers for identification of all LRUs, LLRUs, and other replaceable components on the vehicles, all PTUs and BTEs, gauges, special tools, and spare parts. A form shall be designed to input the SEPTA Class/Lot numbers into the associated field, and shall be submitted to the Engineer for **approval** prior to use.

20.4.6.5 Vehicle History Books

Each vehicle shall have a Vehicle History Book that reflects the configuration and testing status of the vehicle and a truck history book for each truck.

1. The Vehicle History Book shall accompany the vehicle through the production line and be presented to the Engineer at the time of Conditional Acceptance.
2. As a minimum, each book shall contain the following information:

   a. A Table of Contents listing all subjects of data.

   b. Description, completion dates, and **approval** status of vehicle modifications, and list of modifications pending with expected completion dates.

   c. Hold-point inspection reports, as specified for the Quality Control and Inspection plan (QCIP), after all discrepancies have been eliminated.

   d. List of vehicle defects that were identified by Contractor QA or the Engineer's personnel during construction and the disposition of each as verified by inspection.

e. List of serial-numbered apparatus.

f. List of software and revision identifier for each system at shipment and Conditional Acceptance.

g. Results of the pre-shipment inspection, as specified in the QCIP.

h. Shipping documents.

i. Results of the post-shipment inspection, as specified in the QCIP.

j. Results and **approval** status of each test performed on the vehicle or any part of the vehicle.

k. A truck section that includes axles, wheels, journal bearings, and gear mounting records, including pressing charts, truck weigh tickets, and axle manufacturer serial and heat numbers together with the appropriate serial numbers of the trucks and vehicles on which installed. Include truck frame inspections, truck frame rework/acceptance forms, and external inspection reports, if any.

l. A record of any abnormalities that occur during the manufacture of the vehicle or any of its subsystems, including their authorized, validated, repair procedures.

m. Open item status list that includes conditional acceptance items that may require on-site testing for acceptance, software, door operation, HVAC, etc. This will include any production modifications that the vehicle may not have completed that can be done at Field Site.

n. Shipping Open Item List that includes missing parts, and paint/decal issues.

o. Vehicle weight and computer-generated weigh tickets.

p. A record of manufacturer’s routine test reports of major systems.

3. Submit the format and the Vehicle History Book. See the CDRL Detail section, below, for detailed requirements.

20.5 Manufacturing Control

20.5.1 Communication Between Engineering and Manufacturing

Establish a process to ensure regular communication between the Contractor’s manufacturing group and its engineering group.

Assign specific employees in each group to communicate the following:

1. Engineering changes that affect manufacturing.
2. Manufacturing issues that require engineering input.
3. Engineering solutions or modifications to manufacturing issues that have been implemented by vehicle manufacturer. Include a list of vehicle numbers for implemented changes.

20.5.2 Manufacturing

Comply with the following:

1. Documentation:

   a. All manufacturing activities shall include written procedures, drawings, parts lists, dimensions and tolerances, and explicit criteria defining acceptable results.

   b. Establish a process to verify that procedures, drawings, and other written material used by workers are always the current revision.

2. Fabrication:

   a. Establish methods that comply with design documents and use appropriate fixtures, tooling, templates, and the like to ensure consistent installations.

   b. Have established Inspection Test Plan (ITP) that details controls to ensure accuracy of production fixtures, templates, patterns, tooling masters, etc. Prove the accuracy of production jigs, fixtures, tooling masters, templates, patterns, and similar devices at formally established intervals and adjust, replace, or repair as required to maintain quality and comply with the requirements for standards of workmanship in Section 16, Materials and Workmanship.

   c. Sufficiently develop design, manufacturing, and QC processes such that all vehicle components are identical, interchangeable, fit without interference, and can be assembled without alterations.

3. Prohibited manufacturing activities include:

   a. Modification of parts

   b. Cut-to-fit assembly

   c. Match drilling

   d. All other hand-fitting activities

20.5.3 Worker Training

Workers shall be trained in the work to which they are assigned, including the following:

1. Specific training related to the standards of workmanship specified in Section 16.

2. Specific training relating to following manufacturing procedures, drawings, and processes.

3. Instruction on correct use of tooling, jigs, and fixtures for control of the work.

4. Clear instructions to not proceed if parts do not fit, manufacturing procedures are inadequate, tooling, jigs, and fixtures appear to be poorly maintained or inefficient, or other defects are noted, and to promptly notify QC or manufacturing supervisors.

Certify workers that have successfully completed training and demonstrated acceptable work. Uncertified workers shall not perform work on SEPTA's project.

20.5.4 Supervision

Supervision shall be sufficient to ensure that manufacturing complies with manufacturing procedures and good practice.

1. Supervision shall detect and retrain, or remove, workers not performing in accordance with the specified standards of workmanship and manufacturing processes.

2. Coordinate manufacturing supervision and QC such that there is consistency in expectations and results.

20.5.5 Control Samples

Prepare and submit control samples:

1. Quantity: Four control samples to SEPTA

2. Retain copies of signed validation forms with each sample.

3. Furnish **approved** samples to the subcontractor or supplier, with additional **approved** samples retained by the Contractor and the Engineer.

20.6 Quality Assurance (QA) and Quality Control (QC)

20.6.1 Standards

Plan, establish, and maintain a Quality Assurance (QA) and Quality Control (QC) program that complies with the following standards:

1. ANSI/ASQ/ISO 9001, Quality Management Systems – Requirements (or **approved** equal)

2. FTA Quality Management System Guidelines 2019

The Contractor and subcontractors shall be in compliance with these standards but Certification to these standards is not mandatory.

20.6.2 Subcontractor/Supplier QA/QC

The Contractor's QA/QC program shall be imposed upon all entities within the Contractor's organization and on all subcontractors whenever Contract work is performed.

1. The Contractor may accept established QA/QC plans from its subcontractors and incorporate these plans as part of its overall QA/QC program.

2. The Contractor shall require that each supplier maintains a QA and QC program for the services and supplies that it delivers to Contractor.

3. The Contractor's QA organization shall perform QA/QC activities related to subcontractors, including FAIs, receiving/pre-shipment inspections, and audits, as detailed in the Quality Assurance Plan (QAP) and Quality Control and Inspection Plan (QCIP).

4. Inspect and test materials delivered by subcontractors for conformance to Specification requirements:

   a. Identify and document materials that have been inspected, tested, and **approved** as acceptable to the point of use in the manufacturing or assembly processes.

   b. Establish controls to prevent inadvertent use of nonconforming materials.

20.6.3 QA Organization

20.6.3.1 Scope

The Contractor’s “QA organization” includes the entire QA/QC management structure within the Contractor’s organization, and quality personnel assigned to this Contract.

1. At the Contract level, the QA organization shall include the following:

   a. A dedicated QA Manager

   b. A single point of contact for Quality accountability for the entire Contract

   c. Each person proposed to conduct QA activities, such as FAI’s or audits

   d. Each person proposed to perform QC activities, such as inspections or tests

   e. A Material Review Board, or **approved** equal

2. The Engineer has the right to Approve or disapprove of each person proposed in the QAP as part of the Contractor’s QA organization at the Contract level.

20.6.3.2 Responsibilities

Responsibilities of the QA organization include responsibility for:

1. Establishing processes and activities focused on the prevention of defects in the vehicles through all Contractor and subcontractor/supplier phases from design through manufacture and preparation for delivery.

2. Developing, implementing, managing, and auditing the Contract QC system, including development of a QCIP.

20.6.3.3 Authority

Comply with the following:

1. Authority for the QA function within the QA organization shall be established such that the quality of products under the terms of this Contract shall not be compromised in order to meet schedule and cost projections.

2. Management responsible for QA shall have sufficient authority and organizational freedom to ensure that a nonconforming or discrepant product will not be delivered to SEPTA at any location providing product or services for use on this Contract.

20.6.3.4 QA Manager

Select a QA Manager with appropriate training and experience and submit qualifications.

1. The QA Manager shall have a minimum of three years of recent, continuous experience in Quality Management of a similar type of vehicle manufacture.
2. Once **approved**, the QA Manager shall not be removed without **approval** unless the QA Manager voluntarily leaves the employ of Contractor.
3. The QA Manager shall verify that the QAP and QCIP are fully implemented.
4. The QA Manager shall report to an officer within the Contractor's organization or a top-level manager within the QA organization.
5. The QA Manager shall not report to the Contractor's Project Manager or Production Manager.

20.6.3.5 QC Personnel

Comply with the following:

1. Furnish QC personnel qualified to perform inspections or tests as follows:
    a. With prior experience and training
    b. Certified where required, and verified by testing where applicable
2. Maintain records of quality personnel certification and qualifications and make available for the Engineer's review.
3. Contractor's production personnel may not be used to perform QA or QC activities unless specifically **approved**.

20.6.4 QA/QC Records

The QA organization shall maintain its own quality records and data from its QA and QC activities for the effective operation of the QA/QC program.

These records and data shall be available for review by SEPTA for a minimum of three years after Conditional Acceptance of the last vehicle.

20.6.5 Quality Assurance Plan (QAP)

20.6.5.1 Scope

The QAP shall describe in detail the Contractor's processes for planning, implementing, and maintaining quality in all aspects of both design and construction of the vehicles. Following are minimum requirements:

1. Make specific to this Contract.
2. Include a single point of contact for all Contract Quality activity.
3. Include a company policy statement that clearly defines the authority and responsibilities of each member of the QA organization.
4. Include an organization chart for the QA organization:
    a. Show roles and reporting relationships of each member of the QA organization engaged in this Contract,
    b. Show relationship of the QA Manager and QA Department with top management.
    c. Include a description of the responsibilities of the Contractor's QA organization that references the quality organization chart.
5. Define the responsibilities and authority of personnel who manage and perform work affecting quality.
6. Include all procedures to show compliance to ANSI/ASQ/ISO 9001 standard.
7. Describe how the QA organization will maintain and use its own quality records and data from its QA and QC activities for the effective operation of the QA/QC program.
8. Include a list of personnel certification requirements and describe the process for verification.
9. Include provisions for issuance of a Monthly Quality Assurance report. In this report, include, at a minimum, the following:
    a. Incoming material defective by PO
    b. In-process assembly inspections completed with non-conformance reports by vehicle number
    c. Final inspections completed with non-conformance reports by vehicle number
    d. All completed system testing for acceptance with non-conformance reports by vehicle number
    e. A list of vehicles in production by vehicle number including the assembly stage at the time of report date
    f. A list of vehicles completed awaiting SEPTA inspection
    g. A list of vehicles on production hold due to material shortages

h. A list of vehicle OEM issued non-conformance reports to suppliers with Open/Closed status

i. Open Items List to date with Open/Closed Status

j. A list of all material that has Fire, Smoke and Toxicity requirement which is unresolved or waiting final approval

10. Include QA procedures affecting design, manufacturing, and acceptance site operations:

a. Assign the authority and means to implement these procedures.

b. Include as a minimum written procedures that control the activities listed below:

- Design and drawing production, including technical documentation, engineering changes, deviations, waivers, and FMIs
- Verification that all applicable Specification requirements are properly included or referenced in purchase orders for articles to be used on vehicles
- Transmission of all QA requirements to procurement sources
- Surveillance of subcontractor and supplier quality processes
- Special Processes (for example paint operations)
- Evaluation of procured articles against purchase order requirements
- Verification of the maintenance and use of **approved** drawings essential to effective production
- Verification that basic production operations, as well as all other processing and fabricating, are performed under controlled conditions. Establishment of these controlled conditions shall be based on documented work procedures, adequate production equipment, and special working environments
- Equipment calibration and certification
- Production personnel qualifications and certifications
- Procurement and handling of materials
- Monitoring the Contractor's system for controlling nonconforming materials, whether furnished by the Contractor or a supplier. The system shall include procedures for identification, segregation, and disposition.
- Discrepancy reporting
- Material Review board (MRB) or **approved** equal
- QA records
- Shipping, handling, and storing
- Internal and external audits

11. See the CDRL Detail section, below, for details of the QAP CDRL.

20.6.5.2 Implementation

Once **approved**, the **approved** QAP shall be implemented throughout the course of the Contract. The **approved** QAP and all of the implementing processes, procedures, and manuals are subject to periodic audits by the Engineer.

20.6.6 Measuring Equipment and Tools

20.6.6.1 Measuring and Testing Devices

Ensure the validity of measurements and tests through the use of suitable inspection, measurement, and test equipment of the range and type necessary to determine conformance with Contract requirements:

1. Furnish and maintain the necessary gauges and other measuring and testing devices to verify that components, systems, and vehicles conform to the **approved** design.
2. Make available the Contractor's gauges and other measuring and testing devices for use by the Engineer to verify that the vehicles conform to all Specification requirements.
3. If necessary, make available Contractor personnel to operate the devices and to verify their condition and accuracy.
4. The Engineer shall have the right to Approve or disapprove inspection, measurement, and test equipment that is not of the proper range or type required.

20.6.6.2 Control and Calibration

Ensure that inspection, measuring, and test equipment is identified, controlled, maintained, and calibrated by an **approved** accredited Laboratory:

1. Establish an effective time-cycled or usage-cycled calibration and certification program.
2. Include tooling, jigs, and fixtures used as media for inspection or manufacture in this program.
3. Provide an indication on every verified or calibrated device showing its current status and the date (or other basis) on which inspection or recalibration is next required.
4. Promptly recalibrate devices yielding inconsistent measurements or clearly flawed data before the stated recalibration date.
5. Promptly re-inspect work performed using incorrect, unapproved, or out of calibration equipment. The work is considered invalid, whether delivered to production or to the field.

20.6.6.3 Calibration Records

Record calibration certifications and include as part of the QA records.

20.7 Quality Control and Inspection

20.7.1 First Article Inspections

Perform an FAI jointly with the Engineer on all major components, subassemblies, and the fully assembled vehicle.

1. Purpose: The FAI is a quality inspection. The attributes of the FAI item shall be well documented.
2. Engineer Notice and Participation:
    a. Transmit an individual notice to the Engineer for each FAI, a minimum of 30 calendar days before the FAI.
    b. Engineer participation in an FAI is at the discretion of the Engineer. Lack of participation of the Engineer does not relieve the Contractor of performing an FAI.
    c. FAIs may be waived only at the discretion of the Engineer.
3. Location: FAIs shall be conducted at the point of manufacture.
4. Schedule:
    a. An FAI will not be conducted until the design drawings, type test reports, inspections, and control samples of the article have been Conditionally **approved** or **approved** as Submitted. If Conditionally **approved** drawings are used, the Engineer's conditions for **approval** shall be satisfied at the FAI and represented by the inspection article.
    b. When domestic to SEPTA, schedule no more than one FAI per day and two FAIs per week without prior **approval**. When international to SEPTA, schedule no more than one FAI per week without prior **approval**.
5. Procedure:
    a. Conduct FAIs on the first piece, component, assembly, or system, including BTE, constructed using production materials and tooling.
    b. Conduct an independent FAI to ensure the subcontractor is properly organized and equipped. Submit Pre-FAI report with results to the Engineer upon request.
    c. When appropriate, display the inspection article on a stand or table in a well-lit workspace with skilled labor and all necessary inspection tools and gauges available for any review or disassembly work required by the Engineer.
    d. Retain samples of welds, fit-ups, finishes, and colors, photographs, and FAI documentation, for the duration of the production phase in a secure area at the Contractor’s facilities for reference by the Contractor’s and Engineer’s representatives. These approved samples shall be tracked on a log by Contractor for the Engineer and made available when requested.
    e. FAI item shall have all electrical and pneumatic connections tested.
    f. FAI item shall be subjected to complete routine testing to demonstrate all features and functions are operational.

g. FAI item shall, as appropriate, be used to demonstrate and evaluate accessibility and maintainability.

h. FAI item shall, as appropriate, use all support equipment, such as PTUs.

i. FAI item shall, as appropriate, demonstrate on-vehicle software.

j. **Approved** FAI items shall establish the quality of workmanship for the remainder of the same items being produced and for the vehicle. However, it is not the intent that entire items be retained for this purpose, such as a whole propulsion inverter or HVAC unit.

k. When conducting FAIs on BTE, all BTEs shall be networked together.

6. Contract Deliverables: See the CDRL Detail section, below, for detailed submittal requirements.

   a. FAI List: Submit a list of Contractor and subcontractor-supplied equipment that is expected to receive an FAI.

   b. FAI Package: Submit for each FAI that identifies product readiness for the FAI.

   c. FAI Report: Submit for each FAI performed.

7. After **approval** of the Initial FAI:

   a. Equipment shall be shipped from the point of manufacture only after an FAI has been **approved** or waived.

   b. Corrections required as a result of the FAI shall be incorporated into all equipment before shipment.

   c. Changes to product, design, production process, materials, or location of manufacture shall be the basis for another FAI. The scope of the subsequent FAI shall be at the sole discretion of the Engineer.

   d. The initial FAI unit shall be used on a vehicle.

20.7.2 Quality Control and Inspection Plan (QCIP)

20.7.2.1 General

Comply with the following:

1. Develop, submit, and implement a QCIP:

   a. It shall prescribe inspection and testing of materials, work in progress, and complete articles.

   b. It shall include references to all formal inspection and test procedures, including Hold and Witness point inspection.

   c. It shall ensure that all materials, components, and assemblies are inspected for conformance with the **approved** drawings, procedures, and the Specifications.

   d. See the CDRL Detail section, below, for detailed requirements of the QCIP CDRL.

2. As outlined in the QAP, the Contractor's QA organization shall establish, maintain, and audit every 6 months, at minimum, a fully-documented QCIP:

    a. Use a sufficient number of trained inspectors to perform inspections in accordance with the QCIP.

    b. Except as otherwise specified or specifically **approved**, independent testing laboratories shall be located in the United States and require **approval**.

20.7.2.2 Inspection Status

Maintain a system to identify the inspection status of materials and components:

1. Acceptable;
2. Non-conforming; or
3. Not inspected.

20.7.2.3 Control of Non-Conformance

Comply with the following:

1. Give non-conforming materials and components an inspection status of repair, rework, use-as-is, or scrap.

    a. The Engineer will evaluate non-conforming article status and determine the final disposition.

    b. Plainly mark and control non-conforming material in a bonded hold area pending disposition to prevent installation on the vehicle.

    c. Repair, rework, and use-as-is:

        - Shall have **approval** before use.
        - Repair and rework shall be documented and **approved**.
        - Inspection personnel shall verify all corrective actions and mark the discrepancy record.

    d. Scrap: Articles found to be unusable.

    e. Control articles that become obsolete as a result of engineering changes or other actions to prevent unauthorized assembly or installation.

2. Enter on a record any non-conformance noted by the Contractor or the Engineer during assembly.

    a. The record shall accompany the major component, subassembly, assembly, or vehicle from start of assembly through final inspection.

    b. Take actions to correct discrepancies or deficiencies in the manufacturing procedures, or other conditions that cause articles to be non-conforming.

c. If non-conformance cannot be corrected by replacing the non-conforming materials, the Engineer will review and Approve (or disapprove) the modification, repair, or method of correction.

d. A list of Non-Conforming Material shall be provided to the Engineer weekly from Contractor that shows all Non-Conforming Material by status.

e. For any truck that was repaired, the Contractor shall supply drawings showing all areas of the truck that require radiography, ultrasonic, magnetic particle, or dye penetrant inspections

20.7.2.4 Levels of Inspection

Perform 100% or sampling inspection for discrete items of work if not otherwise required in the Specifications.

1. Develop sampling procedures in accordance with MIL-STD-1916, ANSI/ASQ Z1.9, ANSI/ASQ Z1.4, or other **approved** approach and submit.

2. Sampling inspection AQL requirements shall not exceed an AQL of 1.5 without **approval**.

3. Submit sampling procedures as part of the QCIP. See the CDRL Detail section, below, for detailed CDRL requirements.

20.7.2.5 Receiving Inspection/Pre-shipment Inspection

Perform inspections at source, upon receipt, or at both locations to verify conformance to acceptance criteria of specifications and drawings:

1. Perform inspections to purchase order requirements, Specifications, and drawing requirements.

2. Retain material certifications and test reports.

3. Specify 100% or sampling inspection for all major subsystem equipment to be purchased.

4. Submit procedures as part of the QCIP. See the CDRL Detail section, below, for detailed CDRL requirements.

20.7.2.6 Inspection of Work In-Process

The Contractor's QA organization shall maintain and direct a force of inspectors to verify that work in its facilities is performed in compliance with the **approved** design drawings, the Specifications, and the **approved** QCIP:

1. Regularly check dimensions, tolerances, and quality of work against the drawings on each subassembly and vehicle.

2. Record discrepancies in the work in accordance with the **approved** QCIP and notify departments responsible for the work of the need for corrections.

3. Document and submit corrective actions.

4. After re-inspection in accordance with the QCIP, notify responsible manufacturing supervision of rework that is rejected, if any.

5. Re-inspection acceptance status shall be indicated by the inspectors by their date and stamp or initials on the original of the discrepancy report, prior to offering the inspection to the Engineer for consideration.

20.7.2.7 Hold- and Witness-Point Inspections

Comply with the following:

1. Hold-Point Inspections: Mandatory inspection points that shall be presented for the Engineer's inspection:

   a. Inform the Engineer of a hold-point inspection with sufficient advance notice to allow Engineer participation.

   b. Hold points shall be used to inspect completed operations or installations and to inspect items that are about to be concealed by subsequent operations.

   c. Post the inspection forms at or near the point of inspection for each vehicle and include in the Vehicle History Book when all discrepancies have been eliminated.

   d. Nonconforming products shall not be released from a hold-point area until all discrepancies have been corrected.

   e. Vehicle movement beyond any hold point without **approval** is prohibited.

2. Witness-Point Inspections: Mandatory inspection points that shall be presented for Engineer inspection:

   a. Inform the Engineer of a witness-point inspection with sufficient advance notice to allow the Engineer's participation.

   b. The Engineer's participation in a witness-point inspection shall be at the Engineer's discretion.

3. Minimum hold-point inspections:

   a. Inbound material requiring Mill Reports to be used as part of items b, c, d, g, h, and j

   b. Each underframe

   c. Each vehicle roof section

   d. Each articulation unit after installation

   e. Each vehicle shell body section before painting

   f. Each vehicle shell body section after painting

   g. Each truck frame

   h. Each assembled truck, prior to installation under a vehicle

   i. Each vehicle roof after equipment installation

j. Vehicle piping

k. Each vehicle floor panels and covering prior to seat installation

l. Each vehicle watertightness test prior to installation of insulation and interior finishings

m. Each vehicle final watertightness test

n. Each vehicle interior wiring, including wiring in electrical cabinets, empty wireway, conduit before being covered by panels

o. Each vehicle interior, including floor heaters, windscreens, seats, interior walls and ceiling, under-vehicle wiring and conduit wireways, and similar

p. Each vehicle exterior

q. Static and dynamic testing

r. Vehicle complete in all respects

s. Final walk-through prior to shipment

t. Upon arrival on SEPTA's property

u. After rework or repairs have been performed on equipment that has completed formal inspection

v. After implementation of design changes and retrofit modifications

w. Other points requested by the Engineer.

4. If work is concealed without conducting a hold- or witness-point inspection listed in the **approved** QCIP, the Contractor shall, at no cost to SEPTA, expose the work and demonstrate conformance of the work with Contract requirements.

20.7.2.8 Final Inspection

Perform a final inspection and schedule and facilitate final inspection by the Engineer:

1. Contractor Final Inspection:

   a. Perform for each vehicle before the Engineer's final inspection.

   b. Correct each workmanship item covered by prior inspection reports before the inspection begins.

   c. Perform after all work is completed according to written procedures.

   d. Include the following acceptance reports and data:

      - Inspection and test
      - Watertightness
      - Vehicle leveling
      - Weighing

2. Engineer's Final Inspection:

    a. Before scheduling, present all open documentation and action items, including the following:

        - Open discrepancies including missing parts
        - Memorandum of Conference (MOC) open items
        - Engineering Change/modification open items

    b. Allow one day for the inspection, or such additional time as may be requested by the Engineer.

    c. During the inspection, all systems shall be operational with use of **approved** special equipment or power supplies.

    d. Make available qualified personnel to accompany the Engineer with the authority to act upon issues encountered during the inspection.

    e. Make available labor and appropriate tools to remove or open and reinstall covers and doors.

    f. **Approval** is prerequisite to the Contractor shipping the vehicle from the Contractor's plant to SEPTA's facilities.

20.7.2.9 Pre-shipment Inspection

After final inspection by the Engineer and resolution of all outstanding items, prepare each vehicle so as to preclude damage during shipment.

1. Conduct and document a pre-shipment inspection in accordance with the **approved** QCIP.
2. The inspection shall be performed for each vehicle scheduled for shipment.
3. The inspection shall confirm that all shipping precautions and checks have been accomplished.
4. The pre-shipment inspection shall also include a walk-through visual inspection to ensure completeness, cleanliness and workmanship.
5. After completion of the pre-shipment inspection, the unit shall be locked, and no additional activity allowed on the vehicle prior to departure.
6. Document the results of this inspection and include in the Vehicle History Book.

20.7.2.10 Post-shipment Inspection

Conduct and document with Contractor and SEPTA designee, a post-shipment receiving inspection in accordance with the **approved** QCIP:

1. The inspection shall be for each vehicle upon its arrival on the tracks at SEPTA's facilities.
2. Document the results of this inspection and include a copy in the Vehicle History Book.

20.7.2.11 Quality Audits

Submit a comprehensive system of planned and periodic audits:

1. The audits shall be performed by qualified personnel not having direct responsibilities in the areas audited.

2. Audit reports and follow-up action reports shall be available to the Engineer for review and **approval** no later than 10 working days after each audit.

3. Audits of subcontractors and suppliers shall be made by the Contractor and may be witnessed by the Engineer.

4. At a minimum, QA audits of subcontractors and suppliers shall be made at the following times:

    a. As a condition of the subcontract or purchase order, prior to start of work.

    b. Within 30 calendar days of scheduling First Article Inspections or services being supplied by the subcontractor or supplier.

    c. When the subcontractor or supplier manufacturing facility or manufacturing process has changed.

    d. When re-audit is warranted due to unacceptable performance, such as nonconformances, schedule impact, or cost overruns.

5. The Engineer reserves the right to conduct independent audits of the Contractor's Quality system, and that of its subcontractors and suppliers, for its effectiveness at any time.

6. At a minimum, QA audits of the Contractor may be made at the following times:

    a. Prior to start of production of the first vehicle shell.

    b. Within 30 days prior to formal presentation of the first vehicle.

    c. When the product manufacturing facility has changed.

    d. When re-audit is warranted due to unacceptable performance, such as nonconformances, schedule impact, or cost overruns.

20.7.3 Open Items List

Throughout the production of the vehicles, develop, maintain, and submit an open items list (OIL) of discrepancies, and their status, associated with each vehicle.

1. The Engineer will review the details of the OIL and furnish comments or concerns.

2. Correct or remedy all items on the OIL to the satisfaction of the Engineer.

3. Document the details of the Final Open Item List and include copy in the Vehicle History Book.

20.7.4 The Engineer's Audit, Inspection, and Visual Documentation

20.7.4.1 Engineer's Inspection Activities

At the Engineer's discretion, the Engineer may perform QA/QC monitoring of work done under this Contract, including monitoring of the Contractor's or subcontractors' QA and QC activities.

1. Such activities do not reduce or alter the Contractor's QA and QC responsibilities, nor reduce or alter the Contractor's obligation to meet the requirements of the Specifications.
2. Following NTP, the Engineer shall have the right of free access to facilities of the Contractor and subcontractors to inspect, examine, and test items during manufacture and shipment, and within a reasonable time after shipment.

20.7.4.2 Engineer's Visual Documentation

The Engineer has the right to document vehicle and vehicle component manufacturing activities, including tooling, fixtures, and similar by the following means:

1. Still photography
2. Motion media, with sound

20.7.4.3 Contractor Provision of Facilities for the Engineer's Use

Make available to the Engineer's personnel in the Contractor's manufacturing facility:

1. A heated, cooled, and adequately lighted private office with desk, chairs, and a worktable large enough to view full-sized drawings.
2. Ready access to modern toilet facilities.
3. A private telephone line, a fax line, and separate high-speed internet access.
4. Copies of all drawings, diagrams, schedules, changes, deviations, and QA records, upon request.
5. A combination copier/scanner/fax machine dedicated to Engineer's use in the private office space.
6. Small refrigerator with freezer.
7. Meter with thermocouple to verify nominal work environment temperatures and testing operation requirements during assembly operations.
8. Parking space for Engineer separate from Visitor Parking close to workspace.
9. Protections for viral risk (like SARS COVID-19), including, at a minimum: face masks, face shields, gloves, daily office sanitations, and daily updates of any on-site employees' positive test results.

20.8 Testing

20.8.1 Master Test Plan

Comply with the following:

1. The master test plan shall include and differentiate between, but is not limited to, all tests as required to be performed by the Contractor and suppliers:
    a. Qualification and material certification tests
    b. Proof of design tests including all required vehicle shell, truck and suspension, and ride quality tests
    c. Production tests and pre-delivery tests
    d. Vehicle acceptance tests
2. The master test plan shall include:
    a. A detailed schedule showing the sequence in which tests will be performed
    b. The time and place of each test to be performed
    c. This document shall be updated monthly and presented as an attachment to the program meeting minutes showing the status of each test procedure, test, and associated report summarized in a spreadsheet format.
3. The master test plan shall be administered by the Contractor's quality assurance department. It shall be the responsibility of the quality assurance department to ensure:
    a. That all inspection and test requirements have been met
    b. Inspection and test data is complete and accurate
    c. Any follow up or corrective action that may be required has been completed
    d. All final reports are complete, accurate, and Specification compliant
    e. The Contractor's quality assurance representatives shall perform inspections at subcontractor and supplier facilities to ensure compliance with all aspects of the Specifications

20.9 Contract Deliverables Requirements List (CDRL)

20-1 Project Management Plan
20-2 CPM Schedule
20-3 Monthly Progress Report
20-4 Preliminary Design Review
20-5 In-Process Design Review
20-6 Final Design Review
20-7 Correspondence and Contract Deliverables Coding Scheme
20-8 CDRL Report
20-9 CDRL Status Report

20-10 Meeting Minutes Format
20-11 Meeting Minutes
20-12 Specifications Compliance Matrix (SCM)
20-13 Construction Photographs
20-14 Sample Drawings
20-15 List of Final Drawings
20-16 Final Drawings
20-17 Modification and Configuration Control Manual
20-18 ECR Form and Procedure
20-19 Vehicle History Books (VHB)
20-20 Draft Training Plan for Manufacturing Workers
20-21 Control Samples
20-22 QA Manager Qualifications
20-23 Quality Assurance Plan (QAP)
20-24 FAI List
20-25 FAI Packages
20-26 FAI Reports
20-27 Quality Control and Inspection Plan (QCIP)
20-28 List of Applicable Industry Standards for Contractor Workmanship

20.10 CDRL Detail

Submit the following in accordance with this Section:

20-1 Project Management Plan:

1. Submit within 30 days of NTP.
2. Organization Chart for the Contractor's staff:
   a. Personnel and responsibilities as listed in the Program Management Organization Chart section, above.
   b. Show lines of both authority and communication.
3. Workflow Diagram:
   a. Elements listed in the Workflow Diagram section, above.
   b. Include company name, affiliation, principal contact and position, and the location at which the work will be performed.
4. CPM (Critical Path Method) Program Schedule:
   a. Include, as a minimum, the following elements for each activity listed in the Program Schedule section, above:
      - Activity ID
      - Activity duration
      - Early start and early finish dates
      - Late start and late finish dates

- Activity float

b. Include a Gantt chart.
c. Include a schedule narrative, describing the overall approach to meeting required milestones and including the elements listed in the Program Schedule section.
d. Include concurrent engineering about the project's parallel paths, which list and track any critical path dependencies.

20-2 CPM Schedule:

1. Update and resubmit the CPM Program Schedule submitted with the Management Plan

2. Submit at least every month.

3. Submit at the same time as the Monthly Progress Report.

4. The schedule shall comply with the requirements for the CPM schedule in the Management Plan.

5. Show actual achieved progress for each activity.

20-3 Monthly Progress Report:

1. Submit each month, starting with the first full month after issuance of NTP.

2. Submit the report for each month no later than the 10th day of the following month (e.g., 10 July for the June report).

3. For work accomplished during the month:

   a. Actual completion dates and start dates.

4. Updated reports, schedules, and other documents:

   a. CDRL Report
   b. Change Status Report
   c. On-going or open engineering items
   d. Status of correspondence
   e. Dates and locations of program review meetings
   f. Change Order log
   g. Vehicle weight estimate
   h. Vehicle Fire Safety Analysis Component Report

5. For the following month:

   a. Estimated remaining durations for activities in progress
   b. Major work activities planned for the following month including vehicles completed, internal Final Inspection, vehicles that have completed final testing, and vehicles accepted by SEPTA ready to ship
   c. Estimated start dates

6. Quality breakdown and status, by system as necessary:

   a. Contractor quality issues, status
   b. Vendor quality issues, status
   c. Activity related to the closure of discrepancies
   d. Projected closure dates for these items

20-4 Preliminary Design Review:

1. Submit PDR documentation that demonstrates that preliminary design complies with the requirements specified in the Preliminary Design Review (PDR) section, above.

20-5 In-Process Design Review:

1. If the Engineer determines that IPDRs for specific systems are necessary, submit documentation showing design progression, and as requested by the Engineer.

20-6 Final Design Review:

1. Submit FDR documentation that demonstrates that the design is essentially complete and that complies with the requirements specified in the Final Design Review (FDR) section, above.

20-7 Correspondence and Contract Deliverables Coding Scheme:

1. Submit within 30 days after NTP.

2. Furnish a coding scheme to identify correspondence and Contract deliverables.

20-8 CDRL Report:

1. Submit within 30 days after NTP.

2. Update and submit monthly.

3. Include the estimated submittal dates, and their current status.

20-9 CDRL Status Report:

1. Submit monthly.

2. Include the following information:

   a. Drawing and document numbers
   b. Revision letter
   c. Drawing title
   d. Date submitted
   e. Transmittal document
   f. Disposition
   g. Document number identifying the disposition

20-10 Meeting Minutes Format:

1. Submit the proposed format for minutes of meetings before the first meeting minutes are submitted.

2. Comply with requirements in the Meetings section, above.

20-11 Meeting Minutes:

1. Submit for each meeting between the Contractor and the Engineer.

2. Submit within ten days after the meeting.

3. Comply with the **approved** meeting minutes format.

4. Include reasonable projected closure dates for each action item.

20-12 Specifications Compliance Matrix (SCM):

1. At least 15 calendar days prior to the Specification Review Meeting, submit an SCM shell in the format that will be used for the completed SCM and monthly updates.

2. Submit the SCM populated during the Specification Review Meeting.

3. Submit monthly SCM updates.

4. Include the following in the SCM and monthly submittals:

   a. A comprehensive list of Specification requirements extracted from the Specifications.
   b. Documentation the Contractor intends to submit to demonstrate compliance with each Specification requirement, such as reports, analyses, system descriptions, manuals, drawings, inspection and test procedures, and test reports.
   c. **Approved** documents that certify compliance with each requirement.
   d. An indication for each requirement when it is compliant.

20-13 Construction Photographs:

1. Submit before delivery of the last vehicle.

2. Progress and finished vehicle photographs, electronic files on USB drive.

3. Minimum 100 views of the vehicle during stages representative of its complete construction.

4. Record the date each picture was taken, the number of the vehicle pictured, and the location on the vehicle on the back of each print.

5. Insert photographs into a suitable album-type binder with transparent pockets.

6. The album shall contain an index that identifies the photographs enclosed.

7. Provide photographs in standard, high-resolution electronic format on a shared network link, available for download by SEPTA.

20-14 Sample Drawings:

1. Submit a sample drawing of each type, showing compliance with specified format and other requirements.

2. Include Contractor's written drawing design guidelines, which shall include specified drawing requirements, as a minimum.

3. Sample drawings types shall include, but are not limited to the following:

   a. Structural drawings
   b. Assembly drawings
   c. Integrated connection drawings
   d. Wiring diagrams
   e. Piping diagrams
   f. Schematic diagrams
   g. Passenger seating/standing drawings by vehicle type/section of vehicle
   h. Interior air circulation feed/return drawings

20-15 List of Final Drawings:

1. Submit within 90 days following shipment of the first vehicle.

2. Identify each drawing that will be submitted as part of the final drawings.

3. The list shall identify each item required to be submitted by the Contractor in the Final Drawings CDRL.

4. Include a drawing tree showing hierarchy and numbering topology.

20-16 Final Drawings:

1. Submit within 90 days following acceptance of the first vehicle.

2. Drawings shall include those listed above in the Final Drawings section and have a supplied index.

3. Drawings shall be supplied on electronic media in the form specified above for Contract Deliverables.

4. Update final drawings to as-built configuration and submit within 90 days after Acceptance of the last vehicle.

20-17 Modification and Configuration Control Manual:

1. Submit within 60 days after NTP.

2. Contractor-developed modification and configuration control plans and procedures.

3. Flow chart showing the process of configuration control.

4. Narrative describing the configuration control process.

5. Details and samples showing how drawing revisions are indicated.

20-18 ECR Form and Procedure:

1. Submit within 60 days after award of Contract.

2. Proposed standard form and procedure for controlling changes to **approved** documents, drawings, and data.

3. The procedure shall include each step required to maintain control of design changes.

4. The form shall include spaces for the following:

   a. A form tracking number
   b. Date
   c. The vehicle serial number and part number affected
   d. Quantity affected
   e. Serial numbers
   f. Corrective and preventive actions
   g. Other information appropriate for the proposed procedure
   h. Contractor and Engineer signature blocks for the change **approval** and also acceptability of the implemented change

20-19 Vehicle History Books (VHB):

1. Submit for format and content **approval** in advance of shipment/Acceptance of the first vehicle.

2. Final **approval** of the VHB format and content will be confirmed with review of the VHB for the first vehicle.

3. Material specified in the Vehicle History Books section, above.

4. Submit a VHB for each vehicle when it is Accepted.

20-20 Draft Training Plan for Manufacturing Workers:

1. Instruction on correct use of all manufacturing tools

2. Procedures for addressing manufacturing issues

3. Instruction on specified standards of workmanship

4. Instruction regarding unacceptable practices.

5. Description of how workers will be tested at the completion of training to certify that they have understood and retained the instruction.

20-21 Control Samples:

1. Submit four samples for each required item.

2. Include validation forms for Contractor and SEPTA signature.

3. After **approval**, retain one sample and furnish one to the appropriate subcontractor or supplier.

4. Maintain a traceability log for Control Samples that shows chain of custody per sample serial number.

20-22 QA Manager Qualifications:

1. Qualifications for the person proposed to be QA manager.

2. Résumé demonstrating appropriate training and experience.

20-23 Quality Assurance Plan (QAP):

1. Submit within 60 days after NTP.

2. Required information as described in the Quality Assurance Plan (QAP) section, above.

3. Organization chart for the QA organization.

4. Organization chart for the Contractor's staff (see Management Plan CDRL)

5. Resumes of each member of the QA organization engaged in this Contract.

6. QA procedures listed in the Quality Assurance Plan (QAP) section, above.

7. Contractors Document Management Policy and Archiving of Business Records Procedure.

20-24 FAI List:

1. Submit within 120 days of NTP.

20-25 FAI Packages:

1. Submit a package for each FAI a minimum of 30 days before the FAI.

2. Include the following as a minimum:

   a. Agenda
   b. Event location
   c. Schedule of activity
   d. All necessary logistics information, including point of contact
   e. Worker certification
   f. Pertinent documentation and status reports, including the following:

      - Drawings
      - Engineering Changes
      - Modifications lists
      - Complete open items list
      - Mill Certifications (Certificates of Conformance shall not be allowed without **approval**)
      - Status of required samples
      - Test procedures and reports
      - Contractor pre-FAI results

- Software documentation, if applicable.
- Special processes, including description and technical data

g. Inspection forms and data sheets for the FAI.

20-26 FAI Reports:

1. Submit a report for each FAI conducted within 15 working days.

2. The report shall include pertinent information, including photographs.

20-27 Quality Control and Inspection Plan (QCIP):

1. Submit within 120 days after NTP.

2. Flow chart identifying major manufacturing and inspection points including source, receiving point, in-process, hold, witness, and final inspection points.

3. Include a list of all inspection and test procedures used in the manufacture and testing of the vehicle, including those performed at the Acceptance site.

4. Inspection forms:

   a. Include a list of all forms used in the production or testing of the vehicles
   b. Include a blank copy of each form on the list

5. Inspection Status:

   a. Include the method used for identifying inspection status

6. Control of Non-Conformance

   a. Include a written procedure for control of rejected (non-conforming) material in all of the Contractor's facilities. The procedure shall include a Material Review Board or **approved** equal.
   b. The procedures shall address identification, segregation, and disposition of non-conforming material.
   c. Include the process for retention of Defective Material Records, and names of Contractor personnel who are familiar with records.

7. Sampling Procedures:

   a. Include a list of parts and material to be inspected by sampling and indicate the type of sampling to be used.
   b. Indicate the standard on which sampling procedures are based.

8. Source/pre-shipment inspection for subcontractor and supplier product. Include the documentation/reports that must be captured.

9. Receiving Inspections:

    a. Include written procedures for documenting how items are inspected at source, upon receipt, or at both locations to verify conformance to acceptance criteria of Specifications and drawings.
    b. Include sample forms or documents for recording receiving inspection results.

10. In-Process Inspections:

    a. Include written procedures and sample forms or documents for recording in-process inspection results
    b. Include inspection for conformance to current, **approved** drawings.
    c. Include a requirement to submit any corrective actions that must be **approved** before implementation.
    d. In addition to steps for initial inspections, include steps for inspection of repairs and corrections for conformance to drawings and the **approved** rework procedures, as needed.

11. Hold-Point and Witness-Point Inspection:

    a. Include a detailed procedure for each hold-point inspection listed in the Hold-Point and Witness-Point Inspection section, above.
    b. Include sample forms or documents for recording hold point inspection results and discrepancies.
    c. Include the approach applied to provide notification of a Hold or Witness point inspection to Engineer's representatives.

12. Pre-shipment Inspection:

    a. Procedure and sample forms or documents to record this inspection.
    b. Identify the documentation that must be captured and retained by the Contractor at a pre-shipment inspection.

13. Post-shipment Inspection:

    a. Procedure and sample forms or documents to record this inspection.
    b. Include steps necessary to find any vehicle damage or evidence of anomalous conditions during shipping.

14. QC testing:

    a. Functional testing
    b. Subject to **approval**, performing statistical analysis, tests, and other QC procedures when appropriate in the QA processes

15. List and samples of all forms proposed to be used for the Contractor's QC activities.

16. Steps that the QA organization must take with regard to suppliers, including supplier audits.

20-28 List of Applicable Industry Standards for Contractor Workmanship

1. Include a list of all applicable standards used throughout each specification section.

20.11 Referenced Standards

The following standards are referenced in this Section:

ANSI/ASQ/ISO 9001	Quality Management Systems - Requirements
ANSI/ASQ Z1.4	Sampling Procedures and Tables for Inspection by Attributes
ANSI/ASQ Z1.9	Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming
ASME Y14.38	Abbreviations and Acronyms for use on Drawings and Related Documents
	FTA Quality Management System Guidelines 2019
IEC 60617	Graphical Symbols for Diagrams (database)
MIL-STD-1916	Department of Defense Test Method Standard: DOD Preferred Methods for Acceptance of Product
NEMA ICS 19	Diagrams, Device Designations and Symbols for Industrial Controls and Systems

END OF SECTION

Table of Contents

Table of Tables

21.1 General

21.1.1 Scope

The Contractor shall equip these vehicles with Communications-Based Train Control (CBTC) equipment to facilitate operation within SEPTA's CBTC wayside infrastructure, and a Bosch Collision Avoidance System.

The supplier of the CBTC equipment shall be as indicated by SEPTA, but the Contractor shall provide and perform integration, testing, and commissioning of the CBTC equipment as follows:

1. Provide the CBTC equipment in the vehicle and provide the functional interfaces between this equipment and the vehicle in accordance with the requirements of the Specifications and CBTC supplier documents.

2. Test and commission vehicle-borne CBTC equipment in compliance with the Specifications and referenced standards, including integration of vehicle-borne CBTC equipment with other vehicle systems and Operator controls.

3. Work with SEPTA-designated CBTC supplier(s) and perform CBTC integration to fully test the functional interfaces prior to delivery of the vehicles at a CBTC test track at the supplier's manufacturing facility. Vehicle supplier shall equip CBTC test track as per design required by SEPTA-designated CBTC supplier(s).

4. Allow for the participation of the CBTC supplier(s) in vehicle-level design reviews and first-article inspections.

5. Develop the interface and facilitate integration with the wayside CBTC system. Furnish the engineering support and design details necessary to safely and reliably interface with wayside equipment and to test vehicle-borne CBTC equipment to meet the requirements of the Specifications and referenced standards.

21.1.2 Description

The CBTC is a safety critical system. Although the specific configuration of the onboard CBTC equipment has not yet been finalized, a general description of each component is shown below. The actual equipment list may vary as the design finalizes.

1. CBTC Control Cabinet with to facilitate the installation of the CBTC Controller, Transponder Interrogator, I/O Controller, CBTC Data Radio and possible accelerometers.

2. CBTC Controls: This constitutes the basic control system.

    a. The controls shall be located in a CBTC control cabinet

3. CBTC Data Radios

    a. One radio shall be installed in control cabinet

    b. Secondary radio shall be installed in secure location on opposite end of vehicle

4. CBTC Data Radio Antennas

    a. Work with the CBTC supplier to equip the vehicle with a CBTC data radio antenna on the roof of the A-End of the vehicle

    b. Work with the CBTC supplier to equip the vehicle with a CBTC data radio antenna on the roof of the B-End of the vehicle

5. CBTC Cab Controls with cab mounting information elaborated in Section 5, Operator's Cab Controls and in the CBTC Cab Switches section, below:

    a. CBTC TOD (Train Operator Display)

    b. CBTC Mode Switch

    c. CBTC Towing Mode Switch

    d. Cab control interfaces:

        - Master Controller
        - Door Controls

6. Transponder Interrogator Antenna and cabling

    a. Contractor shall mount the transponder/interrogator antenna on the nearest truck to the CBTC Control Cabinet, centered between the running rails. If the CBTC-supplier design requires more than one transponder interrogator antenna, provide on multiple trucks as needed.

7. Speed Sensing devices:

    a. Equip the vehicle with CBTC axle end tachogenerators. CBTC supplier requirements to include the following: Four total mounting locations on two axles, on the truck closest to the CBTC Control Cabinet, or if a free axle is available to be dedicated to CBTC, that one axle should be sufficient and equipped with two sensors for redundancy.

    b. LIDAR/Radar sensors shall be mounted above the cab windshield at each end of the vehicle if required by the CBTC supplier.

21.1.3 General Requirements

Comply with the following:

1. All installation and wiring shall be in accordance with the corresponding requirements of Section 16, Materials and Workmanship.

2. Prior to the installation of the CBTC equipment, the operation of control handles, switches, circuit breakers, etc. provided for CBTC operation shall have no effect:

    a. If necessary, the minimum set of wires, devices, or both may be disconnected or removed, subject to **approval**.

    b. Provide the removed equipment in kit form for SEPTA to install at a later date.

c. Properly dress and tie back wires as to length and connecting hardware.

d. Provide instruction manuals for reinstalling wires and hardware and for testing that hardware interface once installed.

3. Electrical, functional, and mechanical interfaces shall comply with IEEE Std 1474.1, IEEE Std 1474.2, IEEE Std 1474.3, and IEEE Std 1474.4. Modifications to this detailed interface design shall be accommodated up to the completion of design review of the Vehicle-to-CBTC Interface Control Document.

21.1.4 Terms

Abbreviated terms are used throughout this Section, and have the following meanings:

1. CBTC system: Vehicle-borne Communications-based train control system.
2. CBTC equipment: Vehicle-borne communication-based train control equipment.
3. Wayside CBTC system: SEPTA’s wayside communications-based train control system (wayside signaling system), comprised of all equipment needed to make the wayside CBTC system function.
4. Wayside CBTC equipment: SEPTA’s wayside CBTC equipment.
5. Signaled territory: Sections of SEPTA’s alignment with wayside CBTC equipment.
6. Non-signaled territory: Sections of SEPTA’s alignment with no wayside CBTC equipment.

21.1.5 Standards

The CBTC system shall conform to the following rules and standards:

1. 49 CFR 200-299, including, but not limited to 49 CFR 235 and 236 and FRA guidelines for 49 CFR 236.
2. The vehicle-borne CBTC system design and manufacture shall comply with applicable requirements and recommended practices included in the following:
   a. IEEE Std 1474.1
   b. IEEE Std 1474.2
   c. IEEE Std 1474.3
   d. IEEE Std 1474.4
   e. IEEE Std 1475
   f. IEEE Std 1476
   g. IEEE Std 1698
3. Use IEEE Std 1475 in the design of interfaces between the CBTC equipment and other vehicle functionality. If there are differences between IEEE Std 1475 and the Specifications as to functionality and configuration, the Specifications shall govern.

21.2 CBTC Vehicle Subsystem Interfaces

21.2.1 General

Comply with the following:

1. Present the details of the CBTC provisions and interface design as a system, consistent with the requirements in this Section.

2. For vital circuits, the vehicle interface with the CBTC shall incorporate failsafe design principles where required.

3. The following sections specify specific interfaces that shall be provided by the Contractor.

4. A typical set of interface signals is shown in Tables 21-1 and 21-2. A more complete set will be furnished during the design process.

5. A typical set of interface signals is shown in Tables 21-1 and 21-2. A more complete set will be furnished during the design process.

TABLE 21-1, TYPICAL CBTC INTERFACE SIGNALS - OUTPUTS

CBTC Outputs	Anticipated Signal Classification
Emergency	Discrete, vital
Traction Operating Mode	Discrete, Network
Penalty Brake Application	Discrete, Network
Signed Tractive Effort	Network
Performance Level	Discrete, double break
Vehicle Speedometer Inhibit	Discrete
CBTC Display Data	Network
CBTC Status Indications (Event Recorder)	Network
CBTC Active	Discrete
CBTC Health Indications (To MDS) (one way)	Network
Alerter Audible Alarm	Discrete
Alerter Indication	Discrete
Event Recorder	Network, Discrete

TABLE 21-2, TYPICAL CBTC INTERFACE SIGNALS - INPUTS	
CBTC Inputs	**Anticipated Signal Classification**
Vehicle keyed in	Discrete, Network
MC Position	Serial, Redundant
CBTC Towing Mode	Discrete
CBTC Control Mode	Discrete, Network
Selected Direction	Discrete
Signed Tractive Effort	Network
Propulsion Degraded Mode	Network, Discrete
Braking Degraded Mode	Network, Discrete
Vehicle Number Sequence	Network
Alerter Input	Discrete
TOD Operator Controls	Network
Master Clock Time Signal	Network

21.2.2 CBTC Vehicle Network Interface

This path provides a mechanism for communication to the local vehicle network, in case such communication is desirable in keeping within the requirements of Section 13, Vehicle Communication Systems and Section 17, Controls, Networks, and MDS.

21.2.3 CBTC Cab Switches

Comply with the following:

1. Provide a CBTC Mode switch, CBTC Towing Mode switch, and a CBTC Bypass Switch as specified in Section 5, Operator’s Cab Controls, and as **approved**:
    a. CBTC Mode switch: Two positions, Automatic Train Protection Mode (ATPM) and Restricted Manual (RM).
    b. CBTC Towing Mode switch: Three positions: Normal, Towing Pull, and Towing Push.
    c. CBTC Bypass Switch: Two positions, CBTC and Bypass.
    d. See Section 5, Operator’s Cab Controls, for mounting details and additional functional information.
    e. The Contractor’s design shall provide the functionality such that in the Restricted Manual or Bypass position, the CBTC shall be inhibited from controlling any part of the vehicle, including emergency brakes, door enable, traction controls, TOD, and general network access.
    f. The number and configuration of contacts shall be determined during design review.
2. Provide an RM Release switch. This switch shall be capable of being sealed in one position.

3. Provide an Alerter button and corresponding Alertness Control System that shall be active when CBTC indicates that the vehicle is in ATO mode.

21.2.4 CBTC Train Operator Display

Comply with the following:

1. The CBTC Train Operator Display (TOD) shall be dedicated for CBTC functionality.

2. The data rate to the TOD shall allow complete screen rewrites at least every 100 ms.

3. Local circuits shall identify to the CBTC TOD whether the cab is active and whether door controls are activated.

4. All CBTC TODs within the vehicle shall be active at all times when CBTC is active to permit monitoring of CBTC activity from the trailing cab.

21.2.5 High Performance Enable

Provide a discrete double-break trainline that when energized by the CBTC enables the high-performance acceleration curve. Each propulsion control unit shall independently read the trainline and report any detectable fault conditions.

21.2.6 Monitoring and Diagnostics

The CBTC shall provide diagnostic information to the MDS for health monitoring and status for the CBTC system.

21.2.7 Vehicle Performance Interfaces

Interface with the CBTC supplier to supply and validate performance of interfaces below as part of vehicle supplier outfit of vehicle with CBTC equipment. Provide nominal, minimum, and maximum characteristic data as part of the Vehicle-to-CBTC Interface Control Document CDRL.

1. Complete tractive effort characteristics as a function of speed, load, and OCS voltage, for motoring and braking

2. Response times from CBTC command change to tractive effort change

3. Rate of tractive effort changes under all conditions

4. Transfer function from CBTC command to tractive effort output

5. Wheel Spin/Slide System operational characteristics

6. FMECA for vital circuits

7. Selected failure mode information for other circuits and systems

8. Propulsion and Braking Test Data

9. EMC Characteristics

10. CBTC Data radio antenna performance requirements and isolation from other vehicle-mounted antennas. Note that the radio bands of 4940-4990 MHz and 2400 - 2483.5 MHz shall be reserved for CBTC data radio functionality. These frequencies shall be incorporated into the Radio Interference Study specified in Section 2, Design and Performance Criteria.

21.2.8 Equipment Installation Interfaces

21.2.8.1 Mechanical Mounting

Where physical information regarding CBTC components has been estimated, those estimates are provided below, along with specific installation requirements. Contractor shall interface and make accommodation for actual CBTC equipment to be installed on vehicle.

6. CBTC Controls: Provide a compartment inside the vehicle or under-vehicle, with an IP68-rated enclosure if the equipment is located under-vehicle. The compartment shall contain CBTC equipment and shall measure 788 mm (31 in) by 534 mm (21 in) by 407 mm (16 in). In addition, adjacent to this compartment, provide space that measures 305 mm (12 in) by 153 mm (6 in) by 305 mm (12 in) to accommodate the terminal blocks for the CBTC wiring interface.

7. Data Radio Antennas: Provide mounting supports and wire rails for up to four antennas (two on each end of the vehicle). The antennas shall be isolated from the outdoor environment but shall be electromagnetically unobstructed from wayside radio emissions. The data radio antennas shall be readily accessible for maintenance. Each data radio antenna is estimated to measure 153 mm (6 in) by 76 mm (3 in) by 76 mm (3 in).

8. TOD Display: Provide mounting provision for CBTC TOD Display inside the Operator cab. TOD display location is specified in Section 5, Operator’s Cab Controls. Ergonomic review shall be **approved** by Engineer.

9. CBTC Mode and Bypass switches: Provide accommodation for the following CBTC mode switches within the Operator cab, as specified in Section 5: Cutout switch, CBTC Mode Selector switch, CBTC Towing Mode switch.

10. Transponder/Interrogator Antenna: Provide mounting brackets that allow mounting without having bolts in tension. A truck-mounted antenna is estimated to measure 406 mm (16 in) by 406 mm (16 in) by 153 mm (6 in).

11. Tachogenerators: Provide for mounting locations for two possible options, two tachogenerators mounted on both ends of a free axle, or four tachogenerators mounted two each on two powered axles.

12. The vehicle design shall include a minimum weight allocation of 204 kg (450 lb) for CBTC equipment.

21.2.8.2 Connections

Provide cables, wires, junction boxes, conduit, raceways, etc. that are necessary to interconnect CBTC equipment and to connect CBTC equipment to vehicle equipment as **approved**. Provide any shorting-jumpers that may be necessary for vehicle operation prior to the installation of the CBTC equipment.

21.2.8.3 Interconnecting Wiring

Comply with the following:

1. Provide **approved** wiring support and isolation for all CBTC wiring between CBTC components and between CBTC and other components. Provide anticipated wiring between CBTC components and other vehicle circuits.

2. Certain circuits require special provisions, such as shielding and physical isolation from other circuits, which will be defined in design review. Conform to these requirements.

21.2.8.4 Temperature

Design the vehicle such that the CBTC equipment is not exposed to temperatures that are greater than requirements specified in Section 2, Design and Performance Criteria.

21.2.8.5 Power Supply

The CBTC equipment shall be powered from the LVPS. Provide appropriate circuit breakers as specified in Section 9, Electrical Equipment.

1. Provide a minimum of three breakers. The ratings of the breakers will be identified in collaboration with the CBTC suppliers, during design review.

2. For purposes of preliminary sizing of the unit batteries, assume a CBTC continuous load of 500 W.

21.2.8.6 CBTC Control Operating Modes

Comply with the following:

1. The CBTC shall use inputs from the cab controls (including the TODs) to select vehicle operating modes.

2. The CBTC shall impose upon the vehicle modes of operation specified in Table 21-3. These modes are distinguished by which equipment controls the traction systems, what performance curve is enabled, and by which equipment provides speed enforcement.

TABLE 21-3, CBTC CONTROL OPERATING MODES		
Trainline Control Modes	**Propulsion & Brake Controlled by:**	**Performance Curve**
ATPM	Train Operator[1]	High
Degraded Propulsion/Braking	Train Operator[1]	Low
Towing Mode (Push)	Train Operator[1]	Low
Towing Mode (Pull)	Train Operator[1]	Low
Restricted Manual	Train Operator	Low
CBTC Bypass	Train Operator	Low

Notes to Table:

1. Except that CBTC shall be allowed to command the removal of power and the application of brake. This mode includes ATPM and other CBTC-supervised manual modes, operation outside of CBTC territory, and operation prior to the installation of CBTC. When under CBTC supervision, the High-Performance Curve is allowed.

3. For Restricted Manual Mode, CBTC shall enforce an adjustable speed limit that both removes power and applies brake using an approved tapered function relative to speed. The speed limit for Restricted Manual Mode shall be initially set to 10 mph (4.47 m/s).

4. There shall be four additional individually adjustable speed limits, enforced by the propulsion system. These speed limits shall remove power when exceeded, allowing the vehicle to coast to higher speeds.

The relationship between the CBTC mode switch, the CBTC Towing Mode Switch, the CBTC Bypass Switch, and the trainline control modes is as shown in Table 21-4.

TABLE 21-4, CBTC SPEED LIMITS

CBTC Control Received by Propulsion	High Performance Enable State	Speed Limit Designation	Initial Setting	Overspeed Set Point
ATPM (Center City Subway)	High	Automatic	35 mph	37 mph
ATPM (Media-Sharon Hill)	High	Automatic	50 mph	53 mph
Towing Mode (Push)	Low	Manual	15 mph	17 mph
Towing Mode (Pull)	Low	Manual	15 mph	17 mph
Restricted Manual	Low		25 mph	27 mph
CBTC Bypass	Low	CBTC Bypass	15 mph	N/A

21.3 Collision Avoidance System

Comply with the following:

1. Provide a Bosch Tram Forward Collision Avoidance System (Type 2) to allow detection of an impending collision with a pedestrian and enforce braking, to respond when operating in mixed traffic or in areas with grade crossings

2. The system shall interface appropriately with propulsion and braking equipment, while working in parallel with active CBTC equipment.

3. Provide forward-facing radar and dedicated CCTV camera, wired to the Bosch Rail Control Unit.

4. Provide a visual indicator to notify the Operator of a penalty brake application, as specified in Section 5, Operator's Cab Controls.

5. Bypass Switch: The cab shall be equipped with a Collision Avoidance System Bypass switch. See Section 5, Operator's Cab Controls, for details.

6. Power Supply: Provide a dedicated circuit breaker for the Collision Avoidance System. See Section 9, Electrical Equipment, for circuit breaker requirements.

21.4 ROADWAY WORKER ALERT SYSTEM

Comply with the following:

1. A Roadway Worker Alert System (RWAS) as manufactured by ProTran, Inc., shall be installed at each cab end of the vehicle. The operation and configuration of the RWAS shall be identical to SEPTA's current RWAS system

21.5 Contract Deliverables Requirements List (CDRL)

21-1	CBTC Design Package
21-2	Vehicle to CBTC Interface Control Document
21-3	CBTC Test Track Design Package
21-4	Collision Avoidance System Design Package

21.6 CDRL Detail

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

21-1 CBTC Design Package:

1. Product Literature:

    a. Manufacturer's product literature and specifications of ATP vehicle-borne equipment.
    b. Provide documentation demonstrating the following:

        - Previous experience in ensuring compatibility between ATP vehicle-borne equipment and wayside train control equipment
        - Design has been in proven successful revenue service operation for a minimum of one continuous year on a North American transit system prior to submittal of the equipment design for **approval**

2. As-Built drawings:

    a. As-built drawings for ATP vehicle-borne equipment that comply with final drawings requirements in Section 20, Program Control and Quality Assurance.
    b. Illustrate mechanical details, mounting arrangements, dimensions and weight of the equipment.

3. Design and Interface Documentation:

    a. Interface documentation shall detail the mechanical and electrical requirements of the interfaces between ATP vehicle-borne equipment and other vehicle systems.
    b. Interface documentation shall include the following:

        - Detailed design description of functionality and how the design achieves each Specification requirement
        - Drawings illustrating mechanical mounting arrangements and wiring layout on the vehicle
        - Power requirements
        - Voltage and current levels
        - Signal formats, and signal timing constraints as applicable
        - Signal load characteristics
        - Wiring requirements, including wire types and sizes, shielding, and conduit provisions
        - Number and type of electrical conductors
        - Spare wiring and connector requirements
        - Provisions to connect ATP test equipment
        - Equipment ventilation and cooling requirements and methods

4. Materials information.

5. Braking model and brake assurance analysis including a detailed description of the following:

    a. Brake assurance device
    b. Interface circuitry
    c. Associated processing functions

6. Brake assurance design.

7. Safe braking analysis.

8. Departure test proposal that describes the initialization conditions, test sequences, pass/fail criteria, and display indications.

9. The Speedometer/ADU design.

10. Fault Management Plan.

21-2 Vehicle-to-CBTC Interface Control Document:

1. Submit a single package of detailed interface definitions for the Vehicle-to-CBTC Interface Control Document. The package shall include definition of the mechanical, electrical, performance, and functional interfaces that are provided. Furnish details such as

communication protocols, voltage levels, current ratings, wiring requirements, terminal locations, terminal types, and connector specifications. The following interfaces shall also be covered in detail:

a. CBTC network interfaces to onboard networks

b. CBTC to propulsion/braking

c. Time synchronization to CBTC

d. CBTC backhaul radio

e. CBTC to MDS

f. CBTC to event recorder

21-3 CBTC Test Track Design Package:

1. Track Layout

   a. Wireless radios and radio coverage

   b. Transponders

   c. Simulated Station 1 and 2

   d. CBTC entry and exit transition areas

2. Back-end Hardware

   a. Server room

      - Zone controller
      - ATS infrastructure

   b. Fiber cable plant and power distribution

21-4 Collision Avoidance System Design Package:

1. Collision Avoidance network interfaces

2. Propulsion and braking interfaces

3. Master Clock to Collision Avoidance

4. Collision Avoidance to MDS

5. Collision Avoidance to event recorder

21.7 Referenced Standards

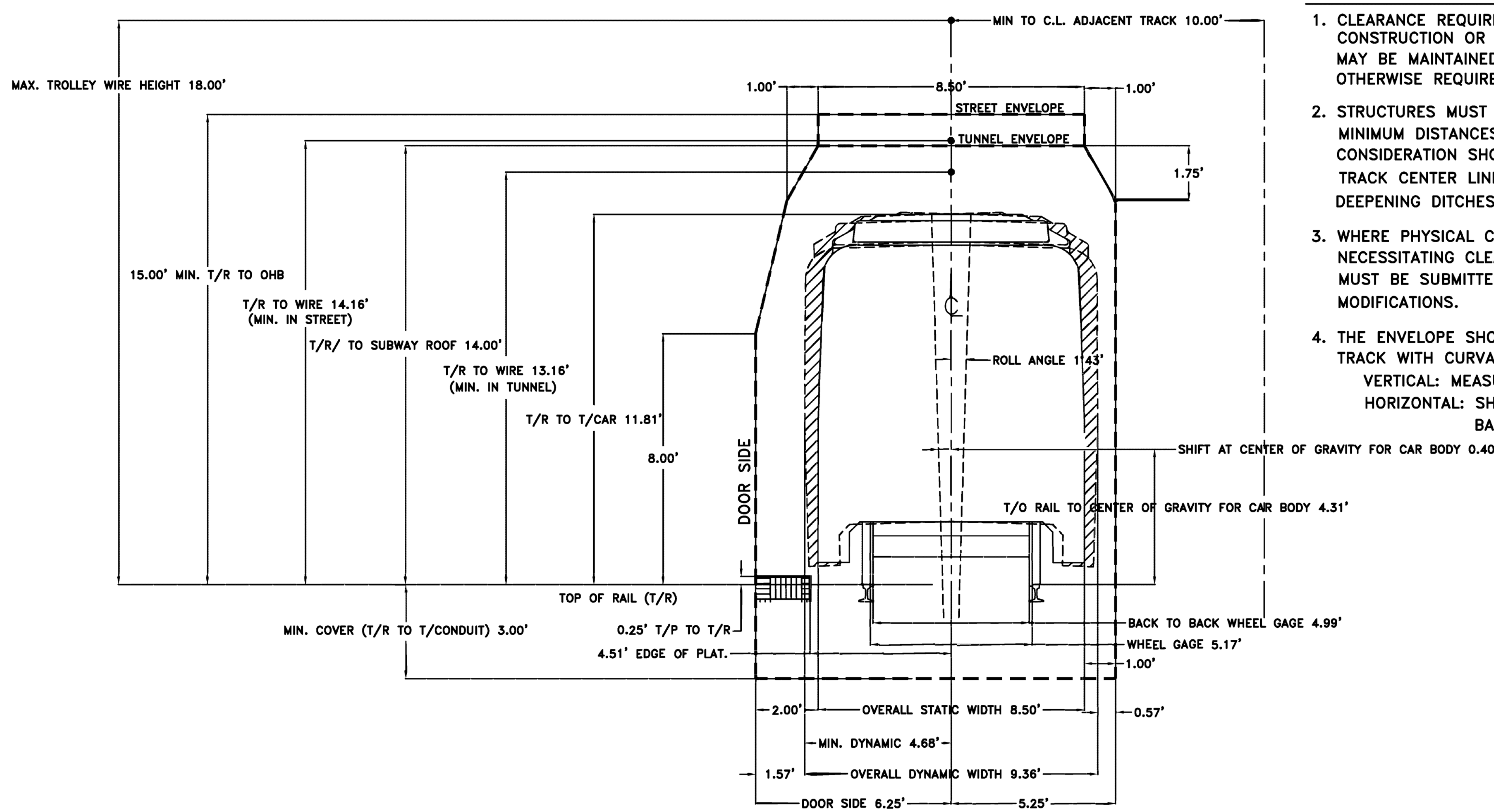
The following standards are referenced in this Section:

49 CFR 200-299	Federal Railroad Administration, Department of Transportation

IEEE Std 1474.1	Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements
IEEE Std 1474.2	Standard for User Interface Requirements in Communications-Based Train Control (CBTC) Systems
IEEE Std 1474.3	Recommended Practice for Communications-Based Train Control (CBTC) System Design and Functional Allocations
IEEE Std 1474.4	Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System
IEEE Std 1475	Standard for the Functioning of Interfaces Among Propulsion, Friction Brake, and Train-Borne Master Control on Rail Rapid Transit Vehicles
IEEE Std 1698	Guide for the Calculation of Braking Distances for Rail Transit Vehicles

END OF SECTION

Appendix A Clearance Diagrams



GENERAL NOTES:

1. CLEARANCE REQUIREMENTS SHOWN ON THIS PLAN APPLY ONLY TO NEW CONSTRUCTION OR RECONSTRUCTION, EXISTING STRUCTURES AND TRACKS MAY BE MAINTAINED AND EXTENDED AT PRESENT CLEARANCES, UNLESS OTHERWISE REQUIRED BY LOCAL OR STATE AUTHORITIES.
2. STRUCTURES MUST NOT BE LOCATED INSIDE THE ENVELOPE SHOWN AND MINIMUM DISTANCES SHOULD BE EXCEEDED WHENEVER POSSIBLE, CONSIDERATION SHOULD BE GIVEN TO INCREASING DISTANCE BETWEEN TRACK CENTER LINES, WIDENING ROADBED SHOULDERS, AND WIDENING AND DEEPENING DITCHES, AND THE STRUCTURES LOCATED ACCORDINGLY.
3. WHERE PHYSICAL CONDITIONS IMPOSE INSURMOUNTABLE RESTRICTIONS NECESSITATING CLEARANCES INSIDE THE ENVELOPE SHOWN, THE MATTER MUST BE SUBMITTED TO THE CHIEF ENGINEER –FACILITIES– FOR ANY MODIFICATIONS.
4. THE ENVELOPE SHOWN APPLYS ONLY TO LEVEL TANGENT TRACK FOR TRACK WITH CURVATURE::
   VERTICAL: MEASURE ALL CLEARANCES FROM HIGH RAIL
   HORIZONTAL: SHALL BE EVALUATED ON CASE BY CASE BASIS BY THE TRACK ENGINEERING DEPT.

REV	DATE	DESCRIPTION	BY	CK'D	AP'D

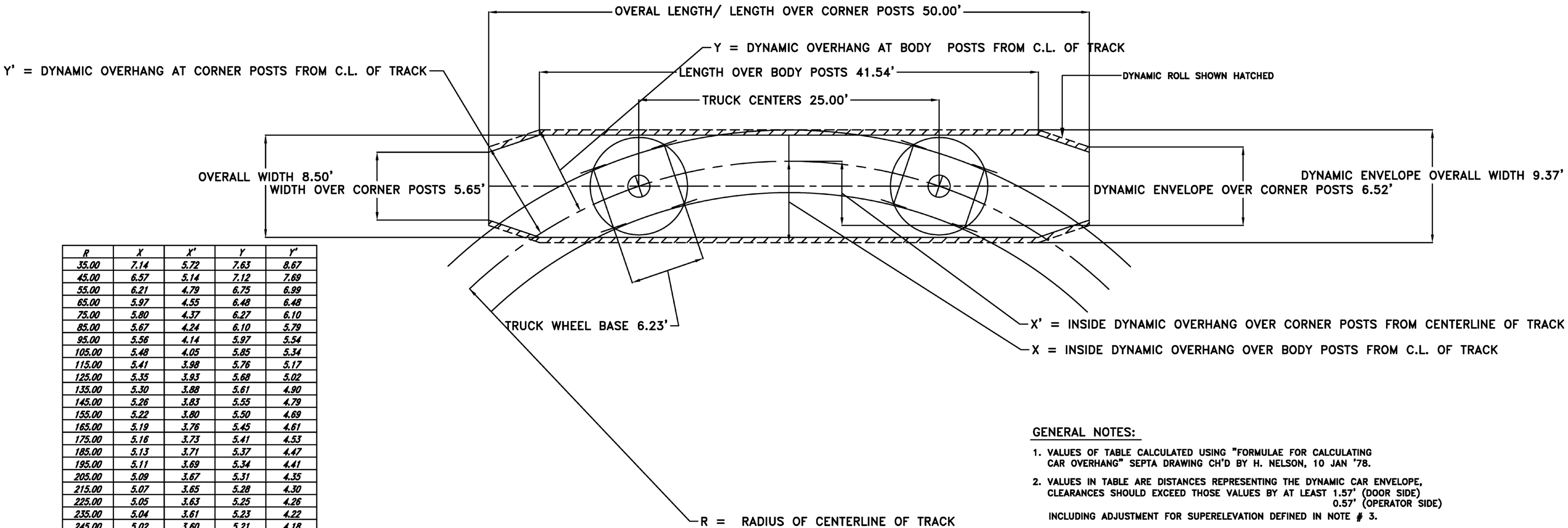
ASST. CHIEF ENGINEER TRACK DEPT. (STEVE THOMPSON)
MANAGER TRACK ENGINEERING (STEVE THOMPSON)
PROJECT ENGINEER (STEVEN ALAN HUMES JR.)

SCALE:
DRAWN BY: SH
DATE: 3/13/02
CK'D BY:
SCALE FACTOR:

SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY
OPERATIONS ENGINEERING
1234 MARKET STREET PHILADELPHIA, PA 19107

SUBWAY SURFACE
LIGHT RAIL DIVISION
KAWASAKI SINGLE END LRV
CLEARANCE ENVELOPE FOR TANGENT LEVEL TRACK
TRACK

WORK ORDER NUMBER
SHEET NO. OF
DRAWING NUMBER
2-W-



R	X	X'	Y	Y'
35.00	7.14	5.72	7.63	8.67
45.00	6.57	5.14	7.12	7.69
55.00	6.21	4.79	6.75	6.99
65.00	5.97	4.55	6.48	6.48
75.00	5.80	4.37	6.27	6.10
85.00	5.67	4.24	6.10	5.79
95.00	5.56	4.14	5.97	5.54
105.00	5.48	4.05	5.85	5.34
115.00	5.41	3.98	5.76	5.17
125.00	5.35	3.93	5.68	5.02
135.00	5.30	3.88	5.61	4.90
145.00	5.26	3.83	5.55	4.79
155.00	5.22	3.80	5.50	4.69
165.00	5.19	3.76	5.45	4.61
175.00	5.16	3.73	5.41	4.53
185.00	5.13	3.71	5.37	4.47
195.00	5.11	3.69	5.34	4.41
205.00	5.09	3.67	5.31	4.35
215.00	5.07	3.65	5.28	4.30
225.00	5.05	3.63	5.25	4.26
235.00	5.04	3.61	5.23	4.22
245.00	5.02	3.60	5.21	4.18
255.00	5.01	3.59	5.19	4.14
265.00	5.00	3.57	5.17	4.11
275.00	4.99	3.56	5.15	4.08
285.00	4.98	3.55	5.14	4.05
295.00	4.97	3.54	5.12	4.03
305.00	4.96	3.53	5.11	4.00
315.00	4.95	3.52	5.10	3.98
325.00	4.94	3.52	5.08	3.96
350.00	4.92	3.50	5.06	3.91
450.00	4.87	3.44	4.97	3.76
550.00	4.84	3.41	4.92	3.67
650.00	4.81	3.39	4.89	3.61
750.00	4.80	3.37	4.86	3.56
850.00	4.78	3.36	4.84	3.53
950.00	4.77	3.35	4.82	3.50
1050.00	4.76	3.34	4.81	3.48
1150.00	4.76	3.33	4.80	3.46
1450.00	4.74	3.32	4.78	3.42
1950.00	4.73	3.30	4.75	3.38

GENERAL NOTES:

1. VALUES OF TABLE CALCULATED USING "FORMULAE FOR CALCULATING CAR OVERHANG" SEPTA DRAWING CH'D BY H. NELSON, 10 JAN '78.
2. VALUES IN TABLE ARE DISTANCES REPRESENTING THE DYNAMIC CAR ENVELOPE, CLEARANCES SHOULD EXCEED THOSE VALUES BY AT LEAST 1.57' (DOOR SIDE) 0.57' (OPERATOR SIDE) INCLUDING ADJUSTMENT FOR SUPERELEVATION DEFINED IN NOTE # 3.
3. ADD 0.05' TO INSIDE OVERHANG FOR EVERY 1/4" (0.02') OF TRACK SUPER ELEVATION.
4. CLEARANCES TO PLATFORMS ARE NOT CONTROLLED BY NOTE #2, BUT SHALL BE THAT DEFINED BY THE TABLE PLUS ANY ADJUSTMENT FOR SUPER ELEVATION PLUS 2" (0.16').
5. ALL CLEARANCES SHALL BE MEASURED RADIALLY FORM CENTERLINE OF TRACK.
6. SEE DRAWING 2-W- FOR HORIZONTAL CLEARANCE ON TANGENT TRACK AND VERTICAL CLEARANCE.
7. ADDITIONAL DOOR SIDE CLEARANCE MAY BE REQUIRED IN ACCESS AREAS.

REV	DATE	DESCRIPTION	BY	CK'D	AP'D

ASST. CHIEF ENGINEER TRACK DEPT. (STEVE THOMPSON)
MANAGER TRACK ENGINEERING (ANTHONY BOHARA)
PROJECT ENGINEER (STEVEN ALAN HUMES JR.)

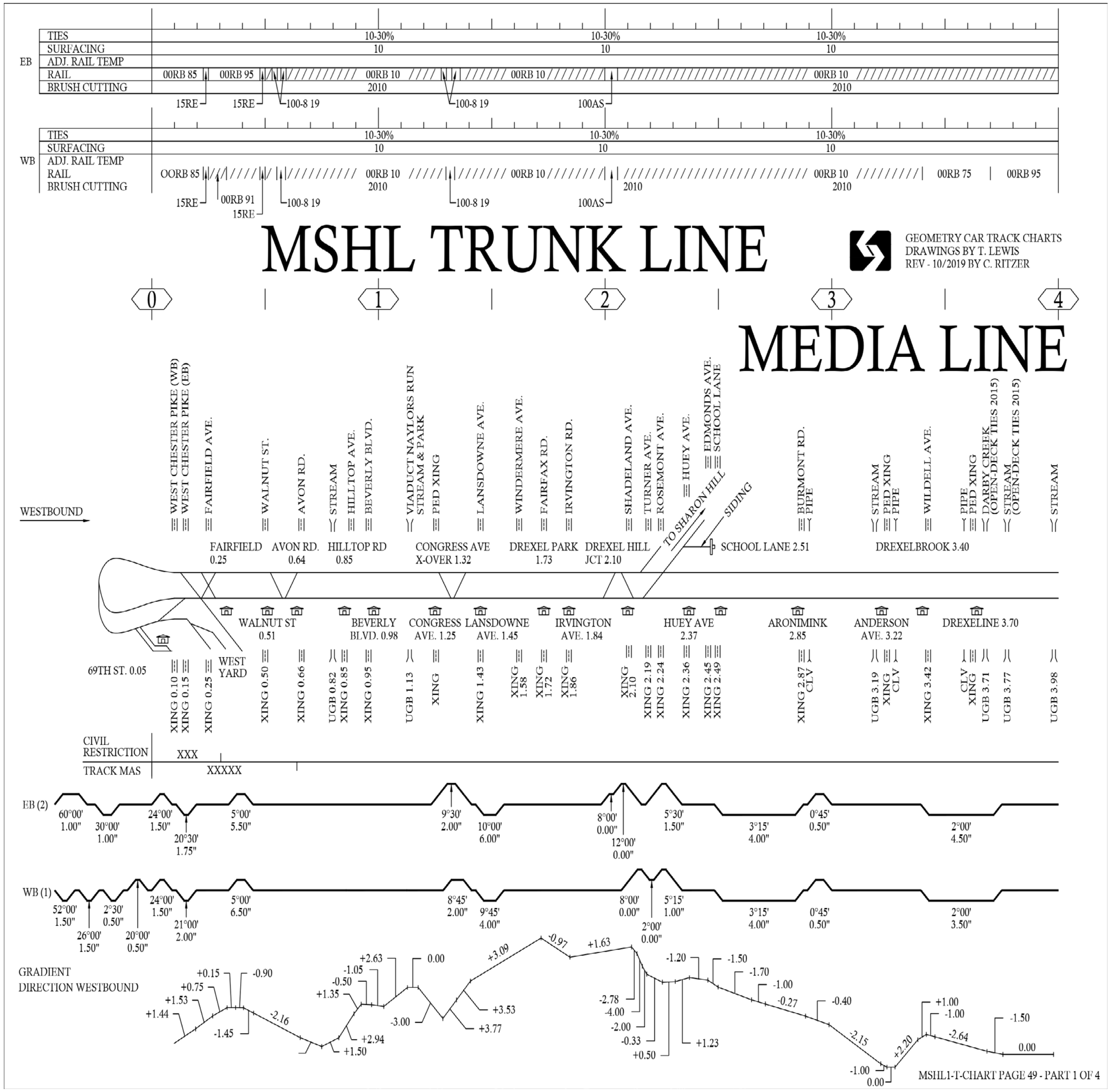
SCALE: 1" = 100"
DRAWN BY: S. HUMES
DATE: 3/12/02
CK'D BY:
SCALE FACTOR: 1

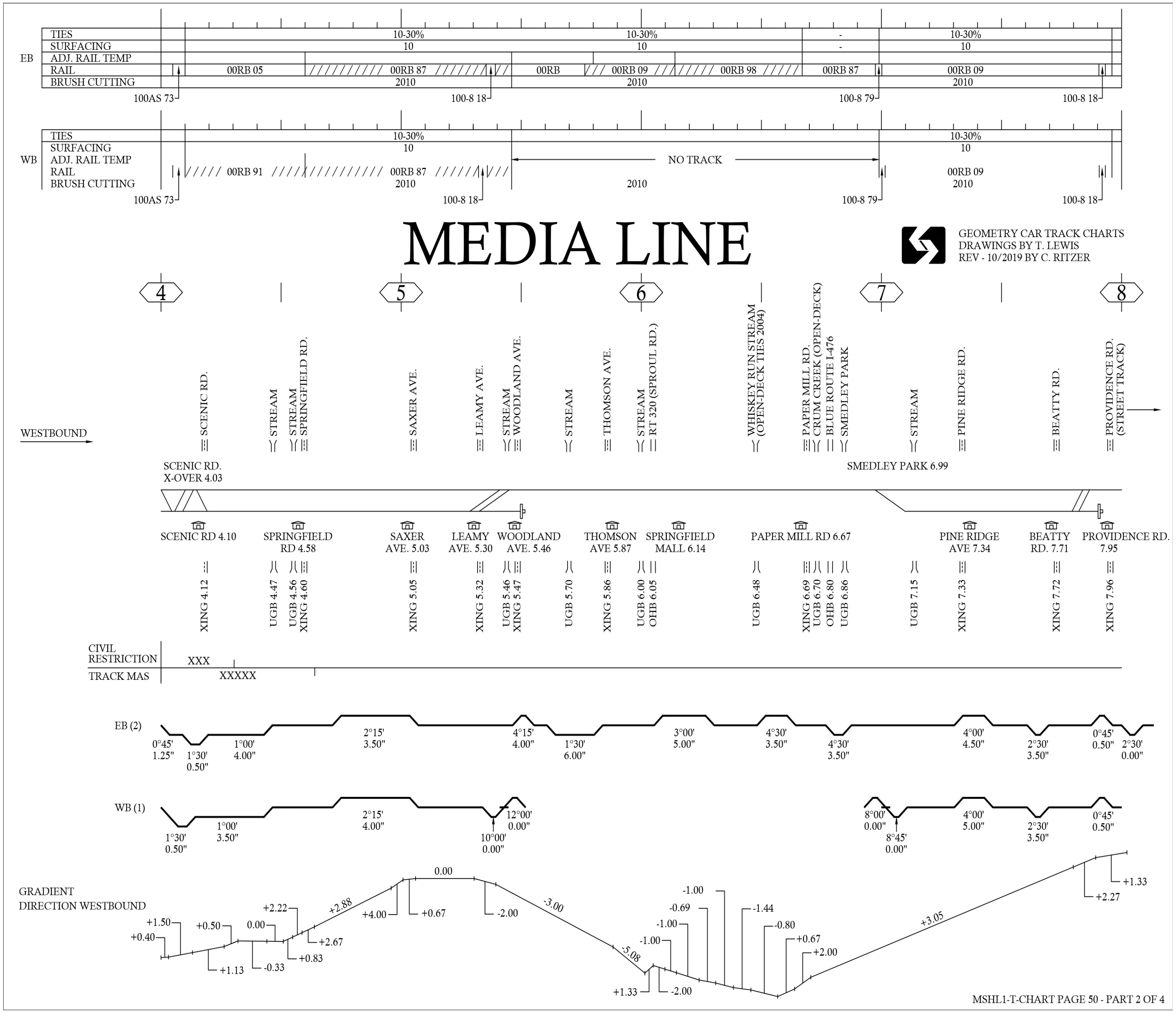
SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY
OPERATIONS ENGINEERING
1234 MARKET STREET PHILADELPHIA, PA 19107

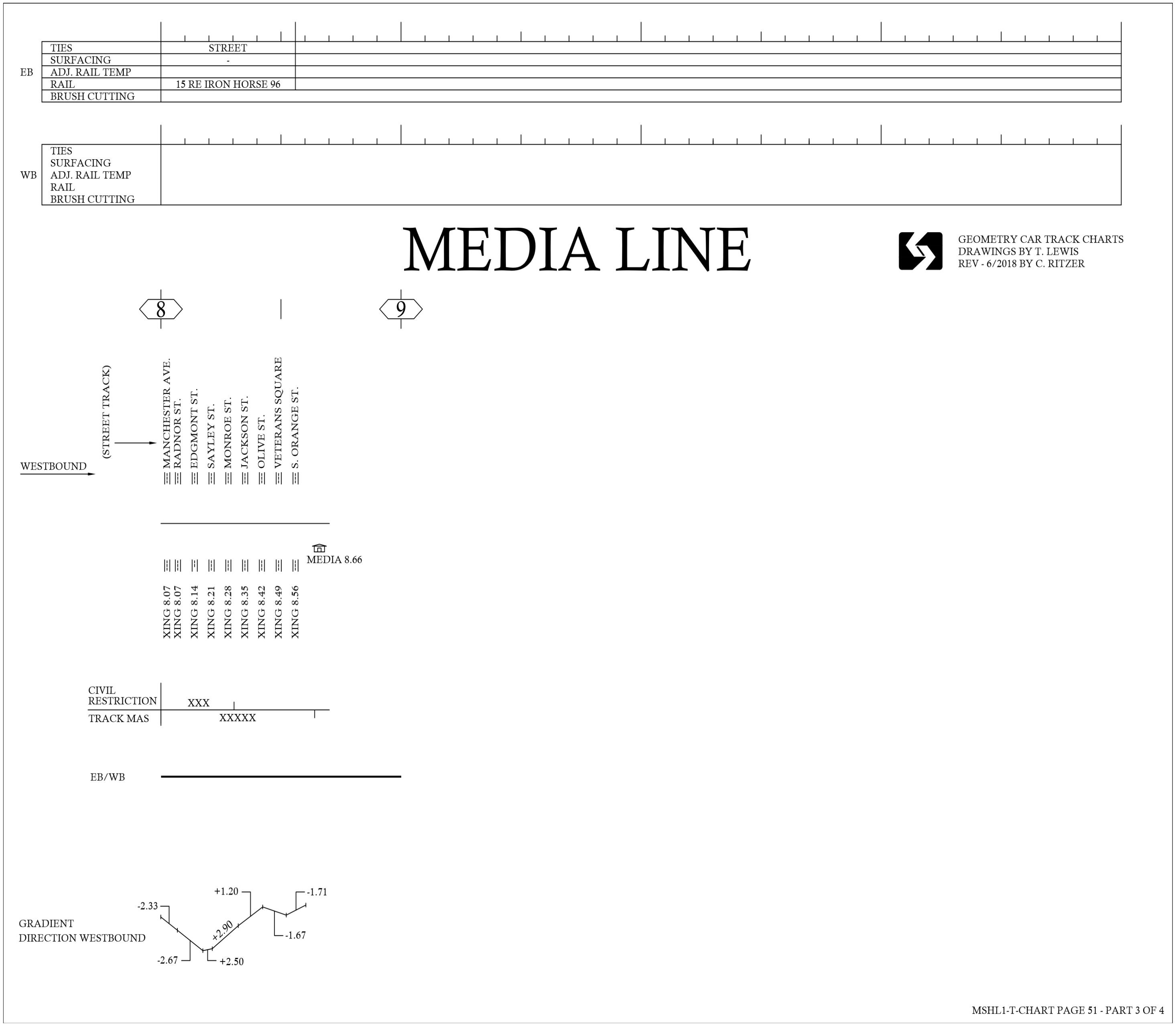
SUBWAY SURFACE
LIGHT RAIL DIVISION
KAWASAKI SINGLE END LRV
HORIZONTAL CLEARANCE ON TIGHT RADIUS CURVES
TRACK

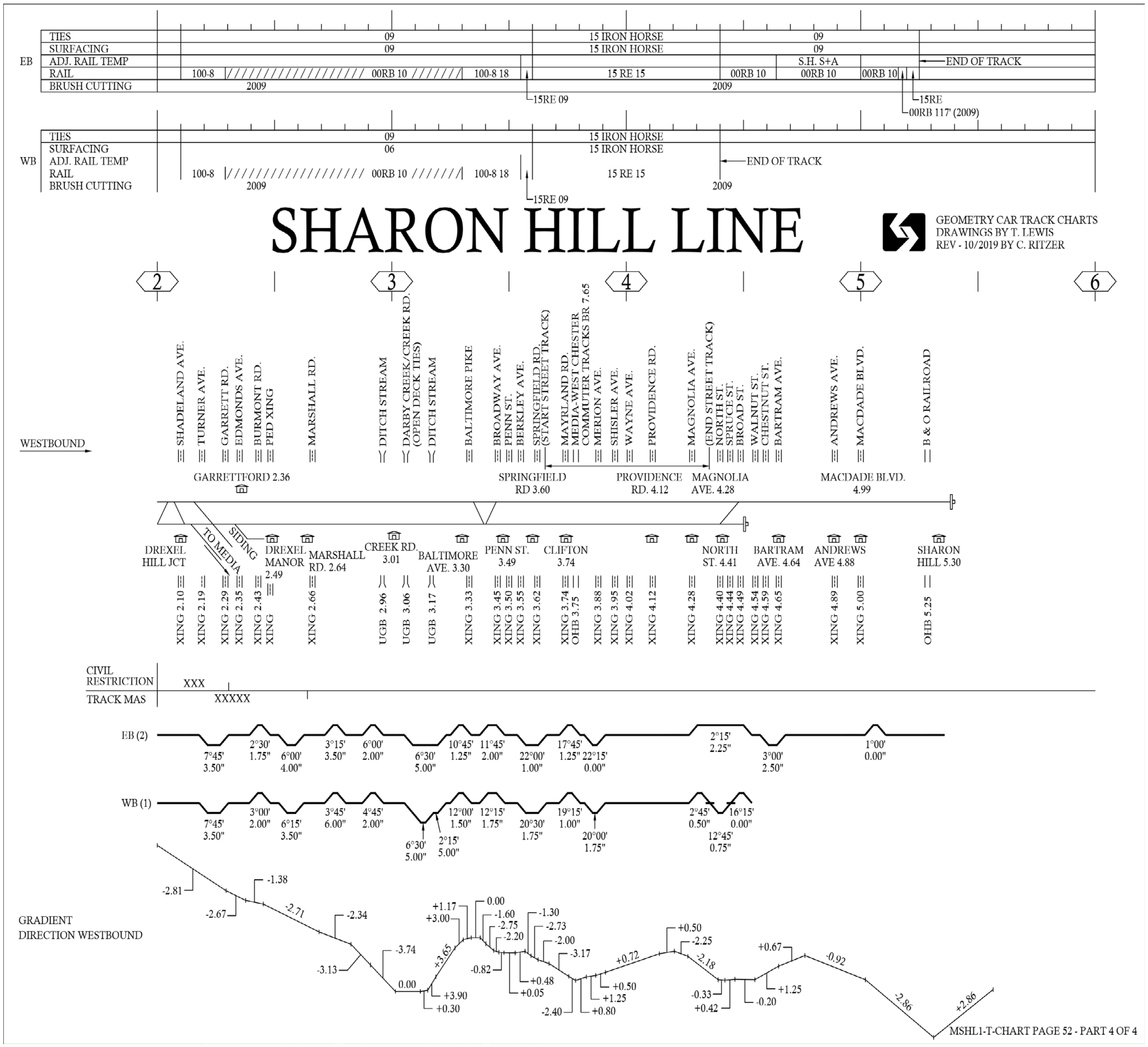
WORK ORDER NUMBER
SHEET NO. OF
DRAWING NUMBER
2-W-

Appendix B Track Charts


MSHL TRUNK LINE
MEDIA LINE
GEOMETRY CAR TRACK CHARTS
DRAWINGS BY T. LEWIS
REV - 10/2019 BY C. RITZER
EB
WB
TIES
SURFACING
ADJ. RAIL TEMP
RAIL
BRUSH CUTTING
WESTBOUND
69TH ST. 0.05
FAIRFIELD 0.25
AVON RD. 0.64
HILLTOP RD 0.85
CONGRESS AVE X-OVER 1.32
DREXEL PARK 1.73
DREXEL HILL JCT 2.10
TO SHARON HILL
SIDING
SCHOOL LANE 2.51
DREXELBROOK 3.40
WALNUT ST 0.51
BEVERLY BLVD. 0.98
CONGRESS AVE. 1.25
LANSDOWNE AVE. 1.45
IRVINGTON AVE. 1.84
HUEY AVE 2.37
ARONIMINK 2.85
ANDERSON AVE. 3.22
DREXELINE 3.70
WEST YARD
CIVIL RESTRICTION
TRACK MAS
EB (2)
WB (1)
GRADIENT
DIRECTION WESTBOUND
MSHL1-T-CHART PAGE 49 - PART 1 OF 4


MEDIA LINE
GEOMETRY CAR TRACK CHARTS
DRAWINGS BY T. LEWIS
REV - 10/2019 BY C. RITZER
EB
TIES
SURFACING
ADJ. RAIL TEMP
RAIL
BRUSH CUTTING
WB
NO TRACK
WESTBOUND
SCENIC RD. X-OVER 4.03
SMEDLEY PARK 6.99
SCENIC RD 4.10
SPRINGFIELD RD 4.58
SAXER AVE. 5.03
LEAMY AVE. 5.30
WOODLAND AVE. 5.46
THOMSON AVE 5.87
SPRINGFIELD MALL 6.14
PAPER MILL RD 6.67
PINE RIDGE AVE 7.34
BEATTY RD. 7.71
PROVIDENCE RD. 7.95
CIVIL RESTRICTION
TRACK MAS
EB (2)
WB (1)
GRADIENT DIRECTION WESTBOUND
MSHL1-T-CHART PAGE 50 - PART 2 OF 4

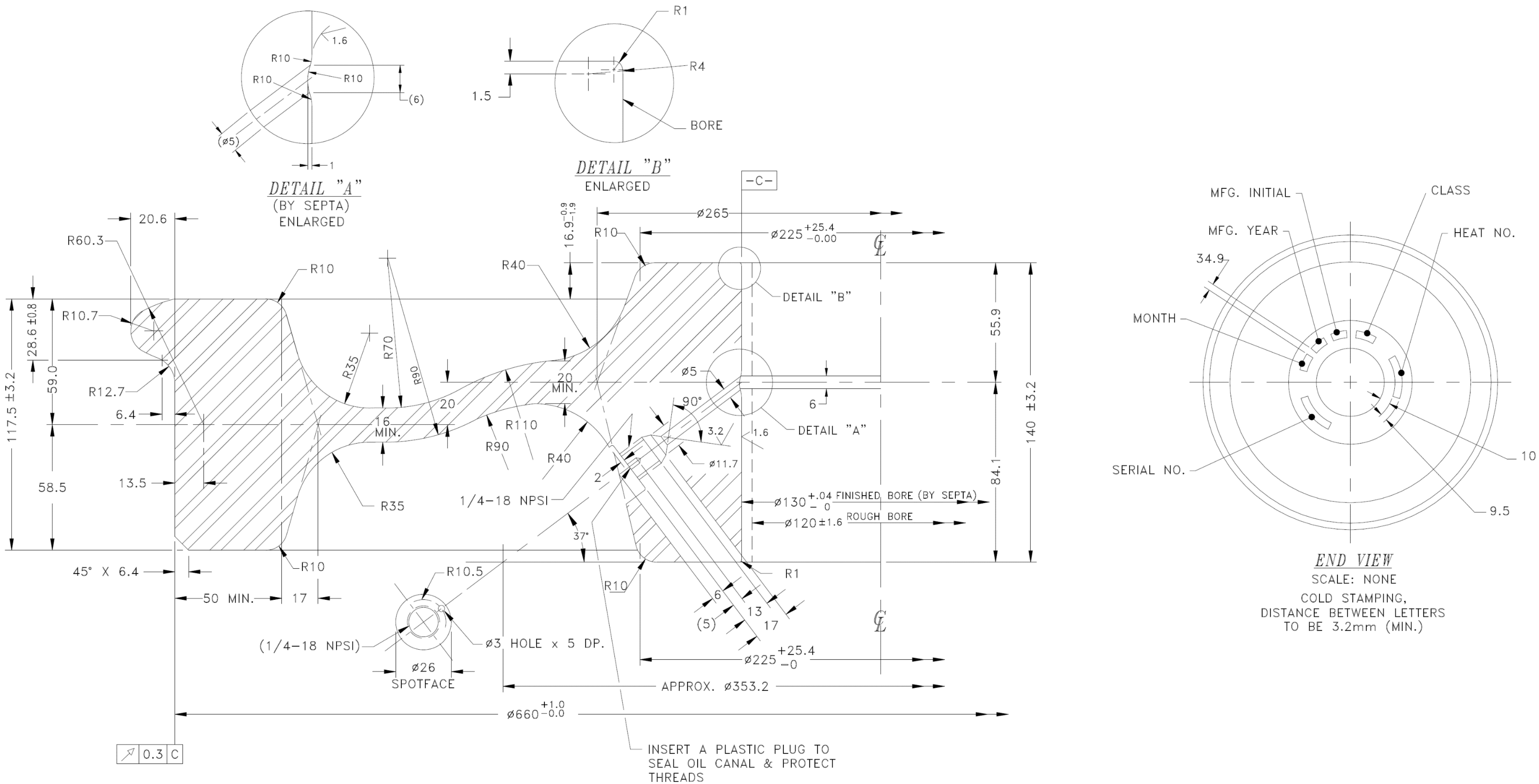

EB
TIES
STREET
SURFACING
-
ADJ. RAIL TEMP
RAIL
15 RE IRON HORSE 96
BRUSH CUTTING
WB
TIES
SURFACING
ADJ. RAIL TEMP
RAIL
BRUSH CUTTING
MEDIA LINE
GEOMETRY CAR TRACK CHARTS
DRAWINGS BY T. LEWIS
REV - 6/2018 BY C. RITZER
8
9
WESTBOUND
(STREET TRACK)
MANCHESTER AVE.
RADNOR ST.
EDGMONT ST.
SAYLEY ST.
MONROE ST.
JACKSON ST.
OLIVE ST.
VETERANS SQUARE
S. ORANGE ST.
MEDIA 8.66
XING 8.07
XING 8.07
XING 8.14
XING 8.21
XING 8.28
XING 8.35
XING 8.42
XING 8.49
XING 8.56
CIVIL RESTRICTION
XXX
TRACK MAS
XXXXX
EB/WB
GRADIENT DIRECTION WESTBOUND
-2.33
-2.67
+2.90
+2.50
+1.20
-1.67
-1.71
MSHL1-T-CHART PAGE 51 - PART 3 OF 4

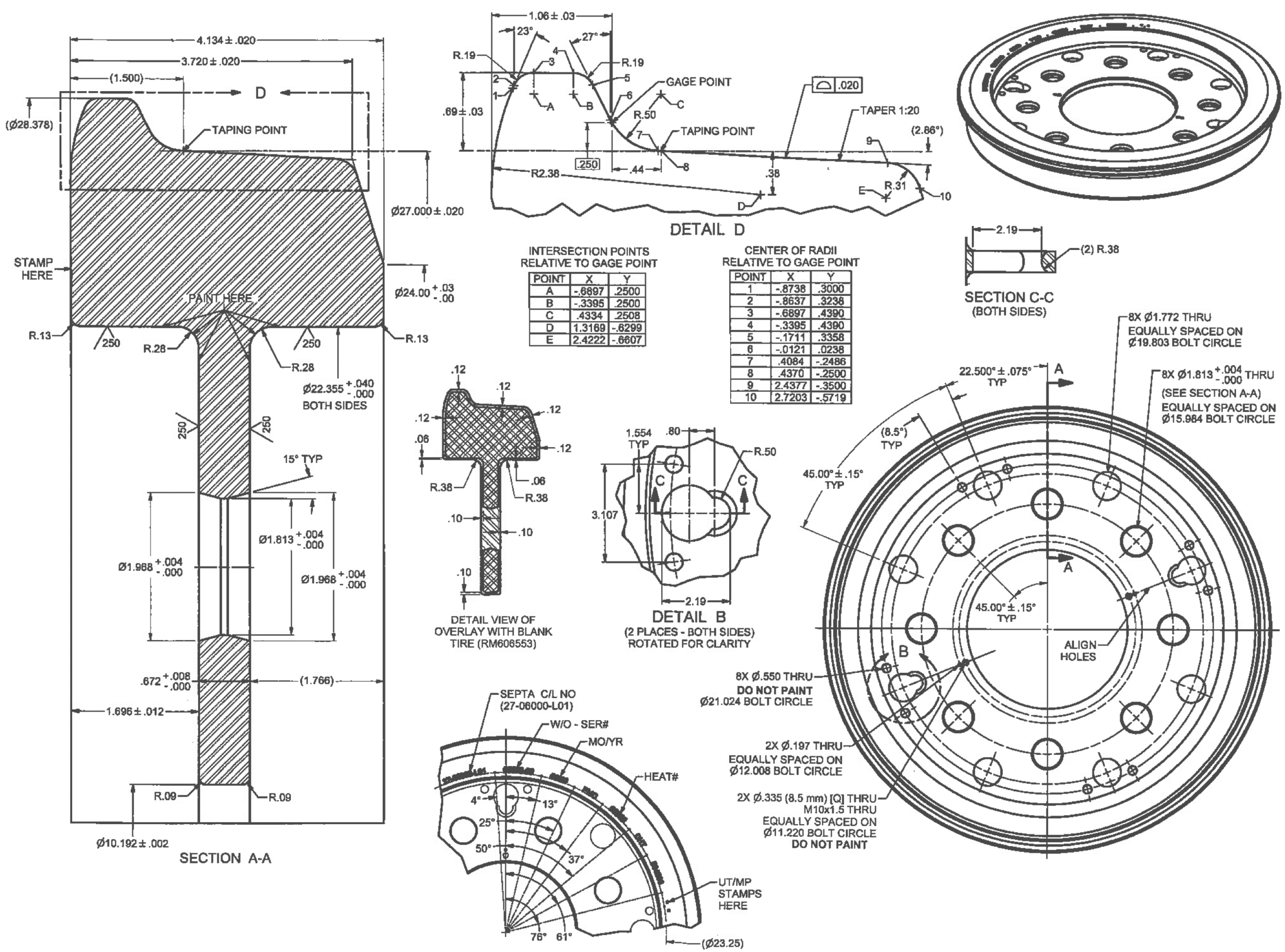

SHARON HILL LINE
GEOMETRY CAR TRACK CHARTS
DRAWINGS BY T. LEWIS
REV - 10/2019 BY C. RITZER
TIES
SURFACING
ADJ. RAIL TEMP
RAIL
BRUSH CUTTING
EB
WB
15 IRON HORSE
END OF TRACK
GARRETTFORD 2.36
SPRINGFIELD RD 3.60
PROVIDENCE RD. 4.12
MAGNOLIA AVE. 4.28
MACDADE BLVD. 4.99
DREXEL HILL JCT
DREXEL MANOR 2.49
MARSHALL RD. 2.64
CREEK RD. 3.01
BALTIMORE AVE. 3.30
PENN ST. 3.49
CLIFTON 3.74
NORTH ST. 4.41
BARTRAM AVE. 4.64
ANDREWS AVE 4.88
SHARON HILL 5.30
WESTBOUND
CIVIL RESTRICTION
TRACK MAS
GRADIENT DIRECTION WESTBOUND
MSHL1-T-CHART PAGE 52 - PART 4 OF 4

Media-Sharon Hill lines provided as examples. City routes to be provided following Notice to Proceed.

END OF SECTION

Appendix C Wheel Profiles


DETAIL "A"
(BY SEPTA)
ENLARGED
DETAIL "B"
ENLARGED
R1
R4
1.5
BORE
R10
1.6
(6)
(ø5)
1
DETAIL "B"
DETAIL "A"
ø265
ø225 +25.4 −0.00
16.9 −0.9 −1.9
R60.3
R10.7
R12.7
R10
R40
R35
R70
R90
R110
R40
R35
20.6
117.5 ±3.2
28.6 ±0.8
59.0
6.4
58.5
13.5
45° X 6.4
50 MIN.
17
R10
20 MIN.
16 MIN.
20
ø5
90°
3.2
1.6
6
ø11.7
1/4−18 NPSI
2
37°
ø130 +.04 −0 FINISHED BORE (BY SEPTA)
ø120 ±1.6 ROUGH BORE
55.9
84.1
140 ±3.2
R1
R10
R10.5
6
13
17
(5)
(1/4−18 NPSI)
ø3 HOLE x 5 DP.
ø26
SPOTFACE
ø225 +25.4 −0
APPROX. ø353.2
ø660 +1.0 −0.0
0.3 C
INSERT A PLASTIC PLUG TO SEAL OIL CANAL & PROTECT THREADS
MFG. INITIAL
CLASS
MFG. YEAR
HEAT NO.
34.9
MONTH
SERIAL NO.
10
9.5
END VIEW
SCALE: NONE
COLD STAMPING, DISTANCE BETWEEN LETTERS TO BE 3.2mm (MIN.)



INTERSECTION POINTS RELATIVE TO GAGE POINT

POINT	X	Y
A	-.6897	.2500
B	-.3395	.2500
C	.4334	.2508
D	1.3169	-.6299
E	2.4222	-.6607

CENTER OF RADII RELATIVE TO GAGE POINT

POINT	X	Y
1	-.8738	.3000
2	-.8637	.3238
3	-.6897	.4390
4	-.3395	.4390
5	-.1711	.3358
6	-.0121	.0238
7	.4084	-.2486
8	.4370	-.2500
9	2.4377	-.3500
10	2.7203	-.5719

Appendix D Current Fleet Data Sheet

LIGHT RAIL VEHICLE (LRV) FLEET

DATA SHEET

i

Document Name: LRV Data Sheet
Revision Date: 8/27/2021

GENERAL INFORMATION

GENERAL INFORMATION	
Manufacturer	Kawasaki Heavy Industries
Build/Delivery Year(s)	1980-1981
Number of Single-End Cars in Revenue Service	112
Number of Double-End Cars in Revenue Service	29
Number of Cars in Non-Revenue Service	0
Fleet Series Number	Single-End: 9000-9111
	Double-End: 100-128
Maximum Number of Cars in a Train	2
Maximum Passenger Capacity Per Car	Seated (Single-End): 51
	Fully Loaded (Single-End): 101 (from spec)
	Seated (Double-End): 50
	Fully Loaded (Double-End): 100 (from spec)
Line Length	
Tunnel (13th St to 40th St)	2.5 miles
10	5.9 miles
11	7.7 miles
13	6.15 miles
34	4.95 miles
36	7.1 miles
Route 101 (Media)	8.6 miles
Route 102 (Sharon Hill)	5.2 miles
Minimum Radius on Horizontal Curve	420” (35’)
Average Miles/Year/Vehicle	Single-End: 23,412 miles Double-End: 18,210 miles

PHYSICAL DATA - DIMENSIONS	INCHES	FEET
Length Over Anti-Climbers of One Car	Single-End: 600”	50’
	Double-End: 636”	53’
Length Over Couplers of One Car	Single-End: 698.4”	58’ 2.4”
	Double-End: 660”	55’
Maximum Width of Car	Single-End: 102”	8’ 6”
	Double-End: 106”	8’ 10”

Document Name: LRV Data Sheet
Revision Date: 8/27/2021

Overall Height of Car from Top of Rail	130.5”	10’ 10.5”
Distance Between Truck Centers	Single-End: 300”	25’
	Double-End: 330”	27.5’
Truck Wheelbase	74.75”	6’ 2.75”
Track Gauge	62.25”	5’ 2.25”
Distance Between Top of Rail and Center of Coupler/Drawbar	17” ± 0.5”	1’ 5 ± 0.5”
Distance Between Top of Rail and Top of Anti-Climber	Single-End: 32.9”	2’ 8.9”
	Double-End: 35”	2’ 11”
Wheel Diameter	Single-End Minimum: 24”	2’
	Single-End New Wheel Diameter: 27”	2’ 3”
	Double-End Minimum: 24”	2’
	Double-End New Wheel Diameter: 26”	2’ 2”

PHYSICAL DATA – WEIGHTS	
Weight of Single-End Car at AW-0 (Empty)	57,881 lbs
Weight of Double-End Car at AW-0 (Empty)	60,042 lbs
Weight of Single-End Car at AW-3 (Crush)	72,872 lbs
Weight of Double-End Car at AW-3 (Crush)	75,033 lbs
Weight of Truck	10,500 lbs

TECHNICAL DATA

Propulsion System

LRV receives catenary power, it is equipped with four DC Series 100 hp Motors, with electric chopper control

PROPULSION SYSTEM	
Maximum Tractive Effort	3100 lbs
Maximum Acceleration Rate	3.0 mph/s
Maximum Speed (Service)	51 mph
Maximum Speed (Delivered Design)	Single-End Car: 47 mph
	Double-End Car: 50 mph
Traction Motor HP	100 hp

Traction Motor Voltage	600 VDC
Traction Motor Current	125 A
Maximum Regenerated Voltage	725 VDC
Gear Unit Ratio	Single-End: 8.307:1
	Double-End: 5.784:1

Braking Systems

LRV braking action is actuated via the four listed braking systems below:

- Dynamic braking
- Magnetic track braking
- Applied friction braking on each truck axle
- Spring paralleled park braking

BRAKING RATES	
Full Service	Single-End: -4.0 mph/s
	Double-End: -3.5 mph/s
Emergency	Single-End: -5.37 mph/s (minimum)
	Double-End: -6.47 mph/s (minimum)

Door System

DOOR SYSTEM SPECIFICATIONS	
Open Time	2.5 ± 0.5 s
Close Time	3.5 ± 0.5 s
Maximum Force	N/A
Minimum Size of a Detected Obstacle	1/8” x 1” No Recycle 1” x 1” Must Recycle
Door Sensitivity Type	Single-End: Sensitive Edge on Center Doors Double-End: Sensitive Edge on All Doors
Recycle	Single-End: Center Doors: Yes Front Doors: No
	Double-End: All Doors Yes

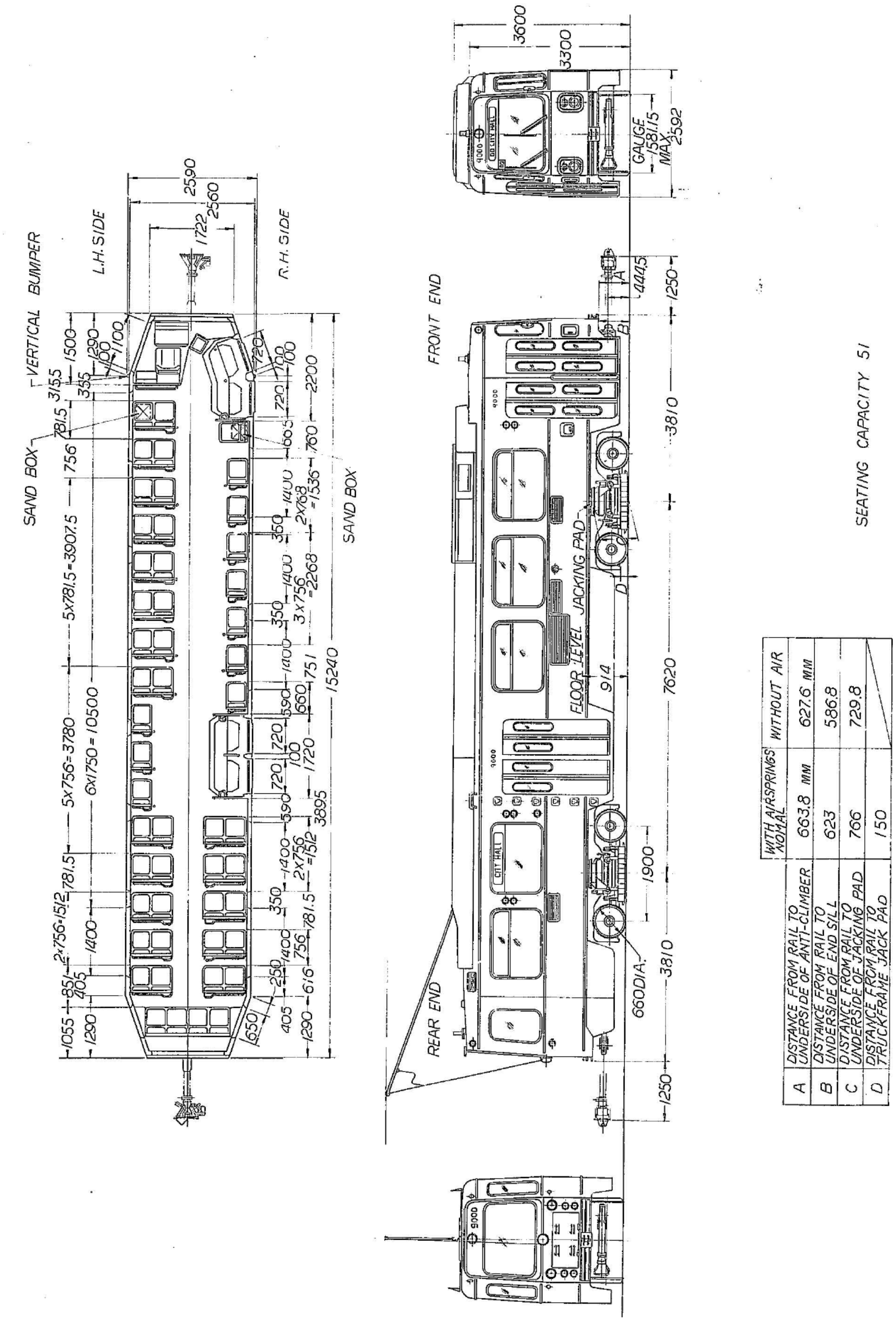
Differences between Cars

DIFFERENCES BETWEEN SINGLE-END CAR & DOUBLE-END CAR	
SINGLE-END	**DOUBLE-END**
1 Cab	2 Cabs
Trolley Pole	Pantograph
Resilient Wheel with Tapered Profile	Solid Wheel with Cylindrical Profile
Fiberglass Seating	Upholstered Seating
4 Doors	6 Doors
Emergency Egress Window	N/A

PASSENGER AMENITIES

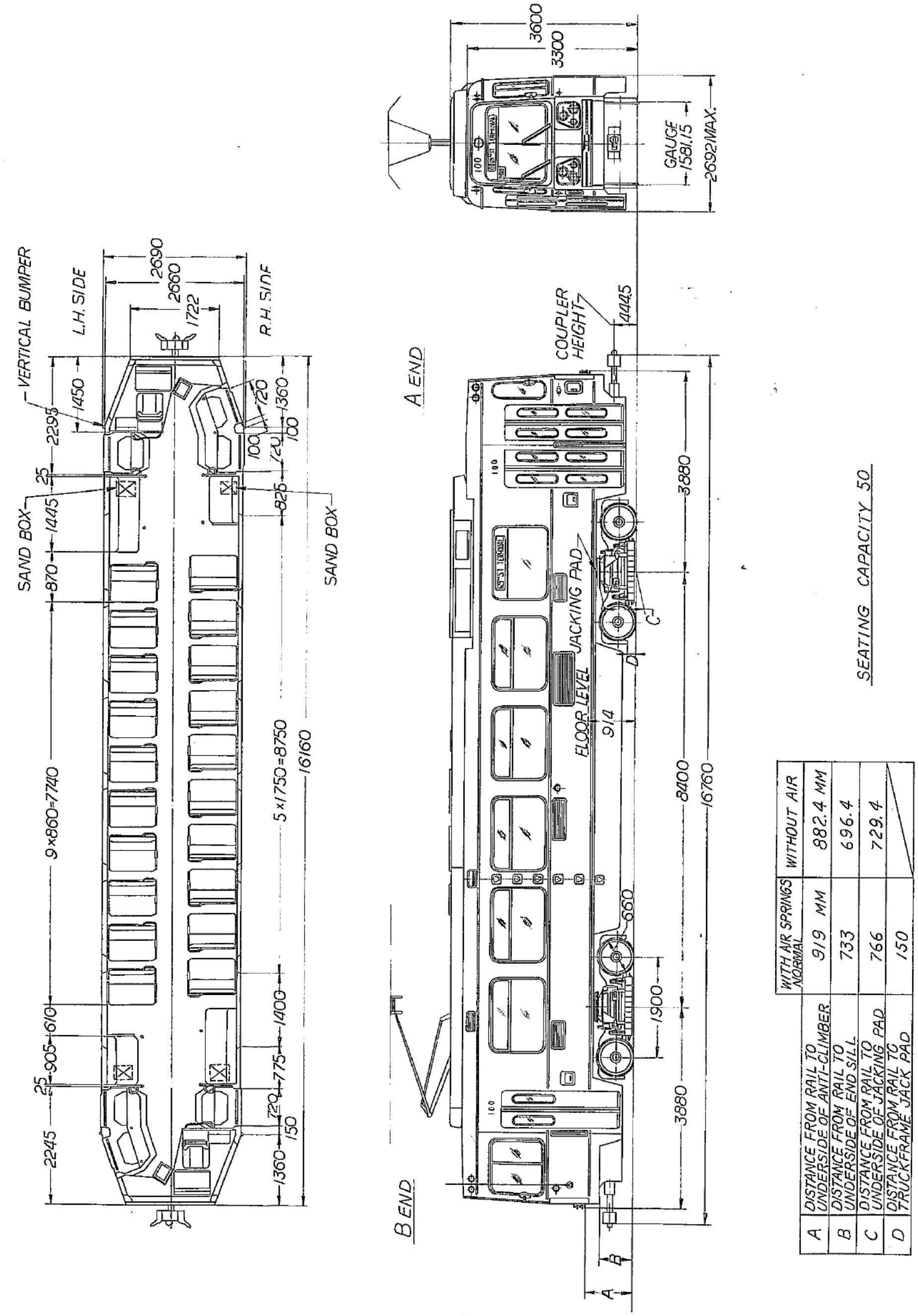
- Public Address System with interior speakers
- Destination sign and corresponding voice annunciation on both exterior and interior
- Interior fluorescent lighting
- Video Surveillance System with 8 cameras per SE car and 12 cameras per DE car
- *Not* Wheelchair Accessible

GENERAL LAYOUT



LRV General Arrangement Single-End Car

Document Name: LRV Data Sheet
Revision Date: 8/27/2021



LRV General Arrangement Double-End Car

Document Name: LRV Data Sheet
Revision Date: 8/27/2021

LIST OF RELEVANT DRAWINGS

TITLE	SEPTA/OEM	DRAWING NO.
General Arrangement Single-End	Kawasaki	*9100001*
General Arrangement Double-End	Kawasaki	*9200002*
Seating Arrangement Single-End	SEPTA	*SK-254*
Subway Clearance Layout	SEPTA	*D-4185*
SE Car Clearance Layout	SEPTA	*SK-358-2*
Truck Assembly for S.E. Car	Kawasaki	*9180010*
Truck Assembly for D.E. Car	Kawasaki	*9280011*
Wheel Tread Profile & Wheel Hub Rough Bore Diameter (SE)	Penn Machine	*PM-8913*
Solid Wrought Steel Wheel Profile (DE)	SEPTA	*D-1367*
Brake Rate Testing ECN	SEPTA	*ECN-3627*

Table of Contents

E.1 General

Provide an Operator Training Simulator (OTS) as specified below. Unless otherwise stated or **approved**, all applicable requirements of the Streetcar Technical Specifications including laws, rules, regulations, and standards apply to this Appendix section as well.

1. Design the OTS to be compliant as a “Type II Simulator” as defined in 49 CFR Part 240.7.
2. The OTS shall comprise one of the two following choices, at the discretion of the Contractor:
    a. An in-kind replacement (the Upgrade Option) of the existing LRV simulators, manufactured by CORYS (Jacksonville, FL), integrating fully with the existing Instructor Stations, Administrator Station, and all hardware and software interfaces with these. This shall include two new Student Cabs. For reference, a copy of the specification that included the existing LRV simulators is included in Appendix F.
    b. A fully standalone system (the Standalone Option), not interfacing with the existing simulator setup in any way. This shall include two Student Cabs, an Instructor Station, and an Administrator Station.
3. The Contractor shall provide for **approval** a cybersecurity plan that outlines the proposed measures to ensure the cybersecurity of the OTS. The software for the OTS shall comply with the requirements for Category B software in Section 18, Systems and Software Engineering.
4. If the Upgrade Option is selected, the Student Cabs shall be powered through either 120 Vac, or through existing power infrastructure. If the Standalone Option is selected, the OTS shall be powered from 120 Vac. In both cases, the OTS shall be protected against power spikes and power losses.
5. As much as practical, OTS components in the Student Cab shall be identical to their equivalents on the car, to allow commonality of spare parts. The design of OTS components not present on the cars shall be robust, intended to serve in a simulator environment, and **approved**.
6. The OTS shall be delivered, installed, and tested for acceptance by SEPTA at least 180 days before the delivery of the first production cars. The OTS shall be updated in accordance with Section E.10.
7. The OTS shall accurately reflect SEPTA operating rules, procedures, and student evaluation guidelines. Conduct meetings with relevant SEPTA departments, including Operations and Training, to ensure that the OTS accurately reflects SEPTA practices in these areas. These parameters shall be presented during OTS design review and FAI.
8. The Contractor is fully responsible for providing a complete, functional OTS that complies with government regulations and the provisions of the Specifications. This includes all required labor, equipment, materials, spare parts, training, and documentation for the design, quality verification, installation, warranty servicing, and setup of the simulator’s hardware and software. If there is uncertainty or contradiction in the requirements, the Contractor shall promptly bring these to SEPTA’s attention for resolution.
9. Coordinate with SEPTA’s IT department to facilitate remote access to the training simulators

at SEPTA’s discretion. The OTS system shall not be designed to require this access for any functionality or warranty servicing.

10. Design life of the OTS system shall be 15 years.

11. All information and intellectual property provided by SEPTA as part of the fulfillment of Appendix E shall remain SEPTA’s property and shall not be copied, transmitted, displayed, performed, distributed (for compensation or otherwise), licensed, altered, framed, stored for subsequent use or otherwise used in whole or in part in any manner without SEPTA's prior written consent.

E.2 Student Cab

Comply with the following:

1. Each Student Cab shall accurately represent the Operator’s area within the cab, forward of but not including the cab partition wall, including the following:

    a. The Approved Operator's seat.
    b. HMI devices and interfaces.
    c. Screens to display the virtual environment, as seen by the Operator, including views through the Exterior Side View CCTV.
    d. Speakers.
    e. An Operator-facing camera.
    f. A microphone.
    g. A tablet, at least 16 inches in size, that will represent controls mounted on the rear wall of the cab and other controls as **approved**.
        i. The tablet shall allow the Student to select the set of controls to be displayed, and to interact with those controls.
        ii. When not in use the tablet shall be stowed in a pocket in an appropriate location in the Student Cab.
        iii. The layout of the tablet’s interface, and the location of the pocket, shall be submitted for Approval during OTS design review.
        iv. The tablet shall be connected to the Student Cab a non-proprietary wired connection.

2. The OTS controls, devices, and components shall replicate the correct status and response to all student actions, instructor actions, and car operation, including emergency situations and fault remediation.

3. All simulations within a given Student Cab (e.g. images, audio, simulated train behavior) shall be matched to one another and the operation of the controls. There shall be no undue lag or delay.

4. Provide both complete and accurate forward and side views.

5. All aspects of door operation shall be simulated, including visuals, sounds, and effects on passengers, but actual door leaves or other associated mechanical devices shall not be included.

6. The Student Cab shall interface with the Instructor Station.

7. It shall be possible to use both Student Cabs simultaneously without any degradation of functionality or performance.

8. The design of the Student Cab shall be presented during OTS design reviews and FAI.

E.3 Instructor Station

If the Standalone Option is selected, provide an Instructor Station that complies with the requirements in this section. If the Upgrade Option is selected, ensure that the Instructor Station complies with these requirements, and enhance its functionality as necessary to ensure compliance.

1. The Instructor Station shall be a computerized workstation designed to support OTS operations, control the OTS, and initialize the OTS, equipped with the following:

   a. A computer and multiple screens as necessary to support the specified functionality.
   b. OTS computers, **approved** no more than six months prior to delivery.
   c. A mouse to dynamically control the inclusion and location of virtual elements.
   d. Total of three tablets, including two spares.
   e. A networked Laser Printer

2. The instructor shall be able to perform the following functions through the Instructor Station:

   a. Select, start, end, pause, fast-forward, and rewind training scenarios.
   b. Start, pause, stop, archive, and refresh training sessions.
   c. Move the student to a specific location on a line.
   d. Trigger specific simulated events.
   e. Insert dynamic objects (e.g., passengers, work crews, vehicles, animals, bicycles) into the training scenario.
   f. Introduce situations within scenarios at will.
   g. Select or modify the level of passenger loading.
   h. Select subsystem failures (degraded operation), introduce faults, and introduce other service-related scenarios such as obstructions.
   i. Monitor the student in real time, including but not limited to Operator's view, view of the Operator, speed, propulsion/braking, active faults, and door status.
   j. Evaluate the student in real time, including inserting markers and comments at specific locations and times for later review.
   k. Program a mode for unsupervised students where no instructor is present.
   l. Create after-action reports database including:
      i. The date, time, instructor, and student.
      ii. The scenarios and situations encountered.
      iii. Time synchronized video snapshots of the student
      iv. A timestamped log of all student interactions with the controls.
   m. Use after-action review tools to assist in reviewing student performance such as performance graphs over duration of the run, recorded video, and recorded sound.

3. The instructor shall be able to leave the Instructor Station and use the tablet to maintain the basic instructor functions specified above.

4. It shall be possible for the instructor to quickly modify existing training exercises and create new ones using templates, click-and-drag mouse controls, and simple keyboard commands.

5. Present the functionality and interface of the Instructor Station during OTS design reviews and FAI.

E.4 Administrator Station

If the Standalone Option is selected, provide an Administrator Station and data administration system that comply with the requirements in this section. If the Upgrade Option is selected, ensure that the Administrator Station and data administration system comply with these requirements, and enhance their functionality as necessary to ensure compliance.

1. The Administrator Station shall include:

    a. One computer tower running the latest version of Microsoft Windows, or **approved** equal
    b. Four 24-inch LCD or LED monitors, with monitor stand(s) as needed
    c. One desktop microphone
    d. One desktop speaker
    e. All appropriate software for the creation and validation of scenarios, training exercises, routes, scoring templates, and equipment, as well as any subcomponents of these. This shall include the ability to create, modify, or remove wayside objects such as scenery. All products of this software shall be fully compatible with the OTS and with any future hardware/software updates.
    f. The ability to operate through scenarios, which shall be identical in experience to the Student Cab except that the controls shall be displayed on the screen and interacted with using a mouse and keyboard.

2. The data administration system shall include:

    a. All appropriate software for the exchange of scenarios and training exercises between the Administrator Station, Instructor Station, Student Cabs, as well as for data management and other administrative functions.
    b. Storage and backup of trainee performance results.
    c. A redundant design so that all stored data is maintained in its current status on a backup unit.

3. The Administrator Station and data administration system's functionality and interface shall be presented during OTS design reviews and FAI.

E.5 Graphics

Comply with the following:

1. Provide high-resolution computer-generated images (CGI) to replicate SEPTA's trolley network including yards, cutbacks, and diversion routes. If the Upgrade Option is selected, the existing simulator's imagery of SEPTA's system may be used.

   a. Regardless of the option selected (Upgrade or Standalone), the Operator Training Simulators shall include updates to trackage, platforms, catenary, signaling, signage, yard changes and additions, and the right of way made as part of SEPTA's trolley modernization program.
   b. Regardless of the option selected (Upgrade or Standalone), the following Trolley Routes shall be modeled, including common trackage such as the tunnel from 13th St. to 40th St.:
      - Route 10
      - Route 11
      - Route 13
      - Route 15
      - Route 34
      - Route 36
      - Route 101
      - Route 102

2. The OTS CGI shall be seamless and smooth panoramic wraparound without image splitting or flickering.

3. All presentations, regardless of number of video displays, shall correctly synchronize with all other presentations.

4. Imagery such as people and other on-track and off-track objects shall be realistic, including motion.

E.6 Audio System

Comply with the following:

1. The OTS shall exactly replicate all sounds of the cab and external environment as defined in the Specifications, including the following:

   a. HVAC
   b. Propulsion and braking, including emergency brake and track brake
   c. Horn/bell/whistle
   d. Opening and closing of doors
   e. Announcements, warnings, and alerts from the cab console
   f. Background radio chatter
   g. Passengers inside the train, passengers outside the train, including passengers banging on the doors
   h. Crossing over bridges
   i. Entry into tunnels and stations
   j. Speed-dependent car sounds, including wheel-rail contact, wind movement, and travel over joints and switches
   k. Use of bridge plates
   l. Audio interactions with passengers and pedestrians
   m. Ambient noises representative of the operating environment

2. The audio system shall use surround-sound.

3. All sounds shall be correlated to student action, car operation, environmental conditions, and images generated within the visual simulation.

4. Doppler effect shall be included as appropriate to indicate the presence of nearby vehicles, passing vehicles, or passing parked vehicles and structures.

E.7 Virtual Environment

E.7.1 General

Comply with the following:

1. Everything in the virtual environment shall be true to scale.

2. All objects shall be clear, visible, and their texture, shape, size, position, orientation, and movement shall be correct under all conditions.

3. Passengers shall seamlessly transition between camera views as they move about all areas of the virtual environment.

4. All people including but not limited to passengers, employees, and contractors, modeled by the simulators shall include a diverse population representative of the multicultural background of SEPTA and its customers.

E.7.2 Virtual Train

The OTS shall accurately simulate the performance of the Streetcars:

1. Include degraded conditions with equipment faulty, cut out, isolated, or otherwise inoperable.

2. All information presented to the student shall match the information presented to the Operator on the actual vehicle. This includes but is not limited to gauge reading, indicator status, CBTC TOD indication, and TOD information.

    a. The CBTC TOD and associated sounds shall accurately reflect the CBTC system specified in Section 21, Communications Based Train Control.
    b. Regardless of the option selected (Upgrade or Standalone), ensure the OTS accurately represents the proper response of the CBTC system including response to location and surrounding environment.
    c. Regardless of the option selected (Upgrade or Standalone), implement the collision avoidance system on the OTS.

3. The virtual train shall be able to move forward or reverse through the virtual exterior environment.

4. The movement of the virtual train through the virtual environment shall be physics-based, and shall accurately reflect the selected level of:

a. Passenger loading
b. Track grade
c. Track curvature
d. Rail adhesion

5. The virtual train shall be capable of reflecting changes in performance due to degraded modes, system faults, and failures.

E.7.3 Interior Virtual Environment

1. Dedicated imagery simulating the feed from in-car cameras need not be provided. However, the camera feed representing the CCTV exterior side view shall depict passengers transitioning smoothly between the interior and exterior of the car.

E.7.4 Exterior Virtual Environment

E.7.4.1 General

The exterior virtual environment shall be based on the actual view from the Operator's position, including any camera feeds displayed within the cab (for example CCTV exterior side view) as outlined elsewhere in the Specifications.

All objects in the virtual environment shall have sufficient detail to enable determination of their relative position.

E.7.4.2 Chronological and Meteorological Conditions

The exterior virtual environment shall include the following conditions:

1. Time of day, including appropriate light conditions such as sunrise, sunset, twilight, and sun glare.

2. Weather conditions, including clear skies, rain, fog (with varying density), high winds, freezing rain, hail, snow, and blizzard conditions.

3. Track conditions and low wheel/rail adhesion coefficient, including dry, wet, icy, wet leaves, and snow covered, and various spill conditions (e.g., gravel, oil).

E.7.4.3 SEPTA System

The exterior virtual environment shall accurately simulate SEPTA's system, including:

1. All aspects of the entire trolley network alignment, including the right-of-way, track, tunnels, track switches (powered and non-powered), grade crossings, crossovers, turn-outs, frogs, loops, signaling, traffic signals, Vetag, wayside route selection equipment, signage including speed limit signs (permanent and temporary), road signs, station platforms, end terminals, yards, shops, bridges, tunnels, and supporting infrastructure.

2. Buildings, structures, and background images, including commercial, industrial, retail, and residential buildings; educational and recreational facilities; emergency and health services

facilities; bridges, overpasses, parking lots, malls, and other typical buildings and structures found in an urban environment.

3. Key landmarks shall be modelled to represent the operating environment.
4. Trees, water surfaces, and distinct geological formations shall be modeled.
5. The system shall be updated to include all changes to the SEPTA system, including planned changes, that occur or are identified before simulator FAI. SEPTA will provide details and drawings for any such changes to the Contractor.

E.7.4.4 Vehicles and People

The exterior virtual environment shall include the following:

1. A large number and variety of motor vehicles, including:
    a. SEPTA-specific vehicles, including other Streetcars and existing SEPTA LRVs; SEPTA buses; and SEPTA supervisory, service, and recovery vehicles.
    b. Cars, vans, SUVs, light trucks, motorcycles, bicycles, straight trucks, tractor trailers, and emergency vehicles (police, fire, and ambulance services).
2. Vehicles specified in Section E.7.4.4 #1 shall be modelled moving on and adjacent to Streetcar tracks. Vehicle movement shall accurately represent permitted traffic directions. Modeled streets shall include parked vehicles. Cars moving on Streetcar tracks shall be instructor controlled and not automatic.
3. A large number and variety of people, including:
    a. Transit passengers and customers.
    b. Adults, seniors, children, and persons using mobility devices, reflecting the multicultural background of SEPTA customers.
    c. Persons performing a variety of motions and actions such as entering, occupying, and exiting platforms, boarding and alighting trains, etc. At the instructor's discretion, persons shall hold the train doors open, attempt to board a train after the doors have closed, trespass on the tracks or in other restricted areas, walk in front of the Streetcar, etc.
4. The use of the Streetcar Bridge Plates.
5. Work crews or other operational anomalies that may be present during or after service hours, including:
    a. Wayside workers, including SEPTA employees and contractors, wearing SEPTA-specific PPE.
    b. Work sites including cones, beacons, flashlights, flags, and signs, set up in accordance with SEPTA's Rules and Regulations.

c. Wayside maintenance vehicles: two unique vehicles specific to SEPTA shall be modelled and capable of instructor control as trains moving along the track network.
d. Instructor controlled personnel displaying a variety of hand signals selectable by the instructor.

6. Each scenario shall include a base number of vehicles and people autonomously reacting to and interacting with the virtual train and other vehicles, people, and objects within the virtual environment.

7. The instructor shall be able to dynamically create situations, as specified below, that include both compliance and non-compliance by people with laws, SEPTA Rule Books, and social norms.

E.7.4.5 Additional Movable Objects

Up to ten (10) additional instructor-controlled and globally-placeable objects shall be modeled. These objects can include people, vehicles, rail vehicles, and animals. The specific list of additional movable objects shall be defined during design review.

E.8 Scenarios

Comply with the following:

1. The OTS shall be provided with 100 pre-programmed scenarios, as **approved** by SEPTA. These shall include sufficient detail to instruct the Operator in the following:

    a. Train operations, including but not limited to the following:
        i. Operating Operator's console including auxiliary control panels.
        ii. Understanding function of information and options displayed on the Train Operator's
        iii. Display (TOD) and other console screens including CAD/AVL.
        iv. Operating the bridge plates.

    b. Yard procedures, including but not limited to the following:
        i. Performing daily and pre-service tests including brake tests.
        ii. Towing operations.
        iii. Operator's reading of rail alignment, and proper handling of derails and misaligned switches.
        iv. Moving a train on a storage track off the bump post and stopping an appropriate distance from the signal.
        v. Moving the train around a loop track up to the signal.
        vi. Checking for fouling equipment, including other cars, and responding accordingly.
        vii. Entering/exiting a shop properly with the assistance of maintenance personnel.
        viii. Entering/exiting a car wash properly.
        ix. Entering a yard properly and laying up on a storage track.

x. Making safety stops properly.

c. Mainline procedures, including but not limited to the following:
   i. All appropriate procedures, and communication with appropriate personnel, before entering mainline.
   ii. Communication with the SEPTA Control Center when the train loses speed readouts.
   iii. Interaction with trains ahead.
   iv. Proper speed to enter/exit a station.
   v. Proper procedure to bypass a station
   vi. Operator's reaction to a person jumping-off of the platform into the train path as the train enters the station.
   vii. Operator's reaction and communication with the SEPTA Control Center when facing a signal problem, including:
      - A stop signal
      - A dark signal
      - Loss of cab signal
      - Wayside/cab signal nonconformance
      - Route/aspect nonconformance
   viii. Crossover moves, including single track operations.
   ix. Use of cutback and diversion routes.
   x. Entering a rail yard.
   xi. Proper procedures when entering an active work zone, including communication with wayside personnel.
   xii. Stop and Proceed operation.
   xiii. Towing
   xiv. Train recovery
   xv. Station overrun procedure.
   xvi. Reacting correctly to track obstacles, including flooding, snowdrifts, debris on the tracks, vehicles, etc.

d. Troubleshooting procedures for situations including but not limited to the following:
   i. Lack of brake status indication
   ii. Undesired brake application
   iii. Brakes in Emergency occurs.
   iv. CBTC Failures
   v. All Doors Closed and Locked fails to illuminate.
   vi. Road horn fails to activate.
   vii. Passenger intercom fails to activate.
   viii. Public address (PA) audio fails to activate.
   ix. Cab radio transmit/receive errors.
   x. Vehicle will not take power.
   xi. Loss of catenary power, including load shedding condition.
   xii. Master Controller inoperable condition.
   xiii. Resetting low-voltage circuit breakers in accordance with the SEPTA Control Center's
   xiv. command.

xv. Unable to open doors.
xvi. Other common or significant failure modes on the Streetcar fleet, as specified by the Contractor and SEPTA during design review or observed by SEPTA within 12 months of delivery of the pilot cars.

2. The OTS shall include the necessary software-authoring tools to allow SEPTA to modify and develop additional training exercises and scenarios.

3. Present the full list of scenarios and events during OTS design reviews and FAI.

E.9 Situations

The OTS shall allow for dynamic creation of situations by:

1. Selecting a base Streetcar or pedestrian within a scenario and controlling its behavior.

2. Introducing additional Streetcars, existing LRVs, vehicles, additional movable objects, or people into a scenario with either:

   a. A predefined behavior.
   b. Instructor controlled behavior.
3. Controlling wayside, traffic, and cab signals, including CBTC, both by setting the state of the signals/CBTC automatically and by manually changing them at any time (to simulate failures).

4. Controlling train switches.

5. Introducing vehicle faults.

E.10 Updates

Comply with the following:

1. Furnish and install updates, at least every six months throughout the warranty period of the fleet, to ensure that the OTS accurately reflects the Streetcar and all modifications implemented on the fleet. This shall include additional common or significant failure modes on the Streetcar fleet, as specified under Section E.8, Scenarios.

2. SEPTA shall have the ability to implement minor modifications to the OTS, throughout the lifetime of the simulator, independently and at no cost. Minor modifications include the following at a minimum:

   a. Changing the behavior of individual signals.
   b. Adding, modifying, or removing wayside objects such as scenery.
   c. Modifying the student scoring and assessment process to reflect additional or revised procedures or criteria.

E.11 Operation and Maintenance Manuals – Operator Training Simulator

The operation and maintenance manuals for the Operator Training Simulator (OTS) shall include all information needed for operation and maintenance of the OTS. This includes:

1. Complete documentation of the functions and capabilities of the simulator system for each type of user (student, instructor, maintenance technician, system administrator, and any others as appropriate).

2. Detailed instructions regarding the instructor's creation of custom scenarios, modification of existing scenarios, and assessment of student performance.

3. System documentation, including power requirements, electrical schematics, and a two-dimensional drawing of the layout, including dimensions.

E.12 Contract Deliverables Requirements List (CDRL)

E-1 Simulator Conceptual Design Review
E-2 Simulator Detailed Design Review
E-3 Simulator First Article Inspection

CDRL Details

Submit the following in accordance with Section 20, Program Control and Quality Assurance. Include the following in each design package, if applicable, in addition to specific items listed below for each CDRL number:

1. Detail drawings: Top level assemblies, existing fleet coupler assemblies, and other drawings if requested

2. Functional description

3. Control schematics

4. Component ratings: Top level components, and ratings of other components if requested

5. Software functional descriptions: Include top level control parameters and values

Simulator Conceptual Design Review:

1. The Simulator CDR shall allow the Contractor, and all relevant subcontractors, to present the preliminary design approach of all hardware and software being developed and to seek SEPTA's early agreement on the approach to the design of the OTS. Discuss relevant SEPTA rules, regulations, and procedures that shall impact the scenarios and student evaluations.

2. In advance of the CDR, submit all required documentation to allow comprehensive discussion of the parameters in Item 1, including the following at a minimum:

    a. A narrative description of each major item of hardware and software, and the interfaces between these items.
    b. A list of SEPTA rules, regulations, and procedures that impact the scenarios and student evaluations, as understood by the Contractor.

c. Engineering drawings including dimension and weight information for all components being provided or upgraded.

3. Submit the cybersecurity plan as specified in Section E.1.

Simulator Detailed Design Review:

1. The Simulator DDR shall allow the Contractor, and all relevant subcontractors, to present detailed designs of all hardware and software being developed and detailed descriptions of the functional parameters of the simulator.

2. The Simulator DDR shall not commence prior to the conditional approval of Streetcar DDR, unless otherwise **approved**.

3. In advance of the DDR, submit all required documentation to allow comprehensive discussion of the parameters in Item 1, including the following at a minimum:

   a. Latest revisions of all documents submitted for the CDR.
   b. The following for all hardware and software items being provided or upgraded:
      i. Functional descriptions
      ii. Electrical schematic diagrams.
      iii. Assembly drawings
      iv. Maintenance and repair procedures

Simulator First Article Inspection:

1. The Simulator FAI shall allow SEPTA to examine all components of the OTS. The functionality of the OTS shall be demonstrated. The OTS Operations and Maintenance Manual shall be completed, to at least Conditionally Approved status, by this date.

2. If the Upgrade Option is chosen, conduct the FAI using stand-in replacements for SEPTA's existing infrastructure with which the OTS will interface, in a manner **approved** by SEPTA.

3. In advance of the FAI, submit all required documentation to allow adequate SEPTA preparation for the FAI, including the following at a minimum:

4. Latest revisions of all documents submitted for the DDR.

   a. Proposed FAI procedure, including stand-in replacement procedure if the Upgrade Option is chosen.

Referenced Standards

There are no standards referenced in this Section.

END OF SECTION

SEPTA

SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY

TRAINING SIMULATOR

TECHNICAL SPECIFICATION

City Transit Division Rail Training Simulator Procurement Program

SEPTA RAIL VEHICLE ENGINEERING

Revision 4.0

May, 2018

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SEPTA

TABLE OF CONTENTS

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1 SCOPE

These Technical Specifications describe and illustrate the criteria to be used for the Contractor's design and construction of a complete Training Simulator to be operated by the City Transit Division of the Southeastern Pennsylvania Transportation Authority (SEPTA). The complete simulator shall include the operation of multiple types of equipment over the entire territory SEPTA owns and/or operates, including SEPTA's Market-Frankford Line, Broad Street Line & Broad-Ridge Spur, Norristown High Speed Line, and Trolley Lines Routes 10, 11, 13, 34, 36, 101, and 102.

The Training Simulator shall comply in all respects with the requirements and the regulations of the Federal Transit Administration of the United States Department of Transportation and the Pennsylvania Department of Transportation. It is noted that while specific agency regulations and recommendations are called for in this Technical Specification, they shall not be considered to be to the exclusion of all others.

The design criteria and constraints that are known to SEPTA have been specified. Further definition and clarification are anticipated during negotiation. If other factors require definition after Contract award, the Contractor shall be responsible for making those definition requirements known to SEPTA in a timely manner for mutual investigation and satisfactory resolution. The Contractor shall not be relieved of the overall responsibility of providing an adequate design or function.

Unless otherwise specified, the latest revision of all documents referenced in this Specification as of Notice-to Proceed shall apply. It shall be the responsibility of the Contractor to deliver a Training Simulator that complies with all applicable laws, rules, and regulations, enacted as of the date of Notice to Proceed.

In case of conflict between requirements, applicable laws, rules, and regulations, unless otherwise specified, the more stringent shall prevail. In case of other conflicts, the Contractor shall report the conflict and request clarification from SEPTA.

The Training Simulators designed and built under this Technical Specification shall operate as intended under the criteria listed within these documents. The Contractor's submittals to the Engineer concerning design concepts, ability to meet all functional and training objectives, and other required submittals as specified must be approved prior to construction.

1.1 INTENT

This procurement is for all labor, tooling, materials, parts, training, publications, support, warranty, spare parts, and apparatus required for development and manufacturing of a complete and comprehensive Training Simulator system. This procurement is also for all work needed to obtain fully tested and validated software installed on the Training Simulator and related computer systems, ready for operation when presented for final acceptance. Any items of material or equipment which are not

fully described or are omitted in this Specification or the accepted Technical Proposal, but are necessary for the completion of the Training Simulator, shall be considered a part of the scope of supply.

In this Specification all references to "number of days" shall mean calendar days unless otherwise stated.

1.2 SCOPE OF SUPPLY

The Training Simulator shall be comprised of multiple workstations that, when networked, provide a virtual environment that will allow the Trainee to experience operating and handling of equipment over SEPTA's operating territory. The Training Simulator shall be designed to be compliant as a "*Type II Simulator*" as defined in 49 CFR Part 240.7. The Training Simulator environment shall provide for the means of creating and/or modifying existing routes, scenarios and training exercises, and create additional equipment models to suit SEPTA's current and future training needs. The capability for SEPTA to maintain the physical characteristics of the railroad presented within the simulator environment utilizing software tools as provided for within this technical specification is required.

1.2.1 Training Simulators

The Training Simulator shall be of a desktop, quarter cab, AAR stand, or hybrid design and shall be comprised of unique simulators representing five (5) different types of equipment, amounting to a total of eight (8) individual Training Simulator Workstations. The Training Simulators shall be monitored and controlled by two (2) identical Instructor Workstation consoles.

Two (2) Training Simulator Workstations shall be configured for each of the following types of equipment:

- SEPTA M-4 Car
- SEPTA B-4 Car
- SEPTA N-5 Car

Two (2) Training Simulator Workstation shall be configured as a SEPTA LRV with the capability to select from the following configurations when loading:

- SEPTA Single End LRV
- SEPTA Double End LRV

1.2.2 Instructor's Workstations

Two (2) Instructor Workstations shall be configured for instructor use to oversee, configure, and control the training process. Each Instructor's Workstation shall be capable of simultaneous monitoring and control of no less than four (4) Training Simulators, independent of the type of simulator.

The Training Simulator controls, devices, and components shall replicate or simulate the correct status and response to Trainee actions, Instructor actions and vehicle operation, including emergency operations.

The Instructor's Workstations shall allow direct interaction between the instructor and the Trainee(s). The method of providing interaction shall include, but not be limited to, the use of live video monitoring, voice communication, and emulated controls.

Each of the two (2) Instructor's Workstations shall have redundant hardware and software such that either station can independently monitor and control of no less than four (4) Training Simulators while the second station is shut down or otherwise not in use.

1.2.3 Data Administration System

A dedicated system shall be provided and integrated in the Scenario Development Workstation and/or the Instructor's Workstations to coordinate the distribution of data among the various simulators. The Data Administration System shall be designed with redundancy so that all data stored on the primary unit shall be maintained to a current status on a backup unit.

The Data Administration System shall be designed to facilitate the exchange of scenarios and training exercises between the Scenario Development Workstation and the Training Simulators. The Data Administration System shall also provide for a central storing location and backup of Trainee performance results from the computer managed instruction software system.

1.2.4 Scenario Development Workstation

The Scenario Development Workstation shall be a PC-based Workstation with several LCD screens, which essentially duplicate each of the remote simulators with the exception of a physical control desk or cab. The Scenario Development Workstation would use a LCD screen control (desk) emulators, one for each different type of Training Simulator.

The Scenario Development Workstation shall contain software capable of producing and validating new scenarios, training exercises, selecting new routes and equipment, and modifying/maintaining graphic elements within the right of way to maintain the known physical characteristics of the operating environment. All files and elements created using this software shall be compatible with any future software or hardware upgrades. It shall also be capable of distributing these elements to the Data Administration System.

1.2.5 Not Used

1.2.6 Mobile Training Simulator Emulator

A laptop computer shall be utilized as a Mobile Training Simulator Emulator. The Mobile Training Simulator Emulator shall be integrated with an existing Smart Board (or equivalent) and function as a "stand alone" extension of the Training Simulator network. The laptop computer shall contain all hardware and software necessary to emulate the full and complete functionality of an Instructor's Workstation or any Training Simulator with an existing Smart Board (or equivalent). There shall be no requirement for network connectivity to provide this functionality. All cab controls and indicators shall be rendered in CGI. The integration of the laptop computer with the Smart Board (or equivalent) shall also provide the capability to display any developed scenario, training exercise, or Computer Based Training (CBT) module. It shall capable of replaying any of the audio/video content available to the Instructor's Workstation (i.e. Trainee forward field-of-view, overhead helicopter view, etc.). The Mobile Training Simulator Emulator shall be capable of receiving updates from the Data Administration System while connected to the simulator network. The Contractor shall be responsible for providing SEPTA with the laptop hardware requirements necessary to meet the criteria specified above.

1.2.7 Video Surveillance

A high resolution camera shall be installed at each Training Simulator to monitor the Trainee's actions. Each camera shall be positioned to provide an unobstructed view of the Trainee so as to monitor and record hand movements and facial expressions. The video surveillance system shall provide live video at the Instructor's Workstation and record snapshot photos. The video surveillance snapshot photos shall be integrated and synchronized with the training exercise or scenario being performed for future playback and review on the Instructor's Workstation. Recorded snapshot photo files shall be stored on the Data Administration System.

1.2.8 Peripheral Devices

A SEPTA approved networked laser printer capable of printing evaluation reports of each Trainee's performance evaluation shall be supplied.

1.2.9 Software

The Contractor shall define and describe all software needed for all Training Simulators and Workstations. The complement of software tools shall include all version control software, development tools, libraries, and other such authoring tools that are necessary for software development of Scenarios, Training Exercises, Trainee Assessment Reports, and Scoring Templates**.**

All associated manuals and supporting documentation shall be provided. SEPTA shall be granted a no-cost license to use and maintain all software required to operate or maintain the Training Simulators and Workstations for the design life of fifteen (15) years.

Each software release shall be provided to SEPTA via official project correspondence and shall include executables, updated software documentation, updated user documentation, and software description document. An initial release of software executables for each type of Training Simulator and Workstation shall be supplied to SEPTA within 180 days of acceptance of each type of Training Simulator or Workstation.

1.2.10 Documentation

The Contractor shall provide detailed education and training programs that include plans, drawings, publications, and Spare Parts lists required for maintenance, repair, overhaul, testing, providing technical services, and operation of each Training Simulator, Instructor's Workstation, the Mobile Training Simulator Emulator, the Data Administration System, and the Scenario Development Workstation.

SEPTA considers the publications and related education programs which will accompany the Training Simulators and all associated equipment, hardware and software to be of great significance and a major contributing factor to the successful creation and usefulness of the Training Simulators. Accordingly, all publications and education program activities described in this contract shall be submitted for review and approval by SEPTA prior to delivery and acceptance of the Training Simulators. SEPTA shall be provided a minimum of 45 days to review all publications and documents.

The Contractor shall designate in-house personnel dedicated to the organization, interface, coordination and flow of information from the originator of the equipment and the Contractor's integration of the Training Simulator as a whole. The personnel shall monitor and evaluate and edit the level of completeness for each manual to assure submittals to SEPTA for review are complete in terms of being a finished, professional product. The Contractor shall facilitate any and all manual information changes associated to technical changes performed on the Training Simulators after the initial acceptance of both the electronic and/or published versions through the extent of the contract and warranty period of the Training Simulators.

SEPTA shall have the right to duplicate and alter all manuals, training materials, equipment, simulators, and tools delivered by the Contractor. These manuals and training materials shall be considered to be the physical and intellectual property of SEPTA and free from copyright restrictions.

All manuals shall be written in a level of detail to fully explain the working of the systems and their components as applied to the Training Simulator's design. Systems shall be fully explained within the context of their integration within the Training Simulator.

The topics shall be discussed to the extent necessary for a full understanding by persons unfamiliar with the Training Simulator environment, but possessing the basic skills associated with their respective trade specialties and a good knowledge of SEPTA's standard practices and safety requirements.

Manuals required for this program are as follows:

- Simulator and Workstation Instruction Manuals;
- Maintenance and Repair Manuals;
- Parts List;
- Authoring Software User's Manual.

1.2.11 Delivery, Installation & Commissioning

The Contractor shall be completely responsible for correct installation, setup, commissioning, startup, and validation testing of the Training Simulator. The Contractor shall work with the appropriate SEPTA departments and shall supply all of the necessary instructions to ensure proper preparation for the installation of the Training Simulator.

All material and equipment to be delivered by the Contractor to SEPTA shall be shipped prepaid at the Contractor's expense using a common or contract carrier of the Contractor's choice. SEPTA shall not be liable for the payment of any shipping, transportation, delivery, customs, or unloading costs under this Contract.

Training Simulator preparation and installation requirements shall include, as a minimum:

- Technical drawings including the footprint of each Training Simulator and Instructor Workstation and the required facility dimensions.
- Any specialized construction instructions.
- Electrical requirements.
- Temperature and humidity requirements.

The Training Simulators, instructor Workstations, and other related equipment shall be installed in an area designated as the Simulator Training Facility. All equipment is to be designed to meet the following physical limitations of the Simulator Training Facility:

- The individual components that comprise the Training Simulators and the Instructor's Workstation shall be able to pass through a standard 36" x 80" doorway.
- Simulators are to be separated into sound proof rooms or cubicles to be provided by SEPTA approximately 10 feet by 10 feet in size.
- SEPTA does not have a digital network available in this room. Network connections shall be provided by the Contractor.
- Capability for remote access implementation to be provided by SEPTA.
- Contractor must provide a proposed layout as well as infrastructure and environmental requirements for SEPTA's review and approval. **[CDRL 1-01]**

All Training Simulators, Instructor Workstations, and other related equipment will be installed and commissioned at the following location:

SEPTA Training Department
City Transit Division Simulator Training Facility
3rd Floor
1234 Market Street
Philadelphia, PA 19107-3780

All written or printed matter to be delivered to the Engineer, such as technical correspondence, submittals, publications, drawings, etc. shall be delivered to:

SEPTA Rail Engineering
New Vehicle Programs
1234 Market Street
Philadelphia, PA 19107-3780

1.2.12 Training

The Contractor shall provide a SEPTA-approved Training Program. This program shall provide adequate coverage to insure satisfactory operation, servicing, troubleshooting and maintenance of the Training Simulator and all other furnished equipment.

The Contractor may assume that SEPTA's instructors and maintenance personnel have the basic skills pertinent to their crafts, and a high school education. When creating lesson plans and content, the Contractor shall also assume that such students will be new to the Training Simulator environment and its associated systems. Instructional content shall be sufficient to include the context of the subject matter along with theory of operation, troubleshooting, corrective actions for repairs and preventative maintenance instructions.

1.2.13 Spare Parts

The Contractor shall provide Spare Parts for all apparatus and components of the Training Simulators and Workstations in the quantities and configuration listed in the Price Proposal. All assemblies shall be delivered as called for. All items shall be identical with corresponding items as supplied on the Training Simulators and Workstations, and any changes to parts made on the Training Simulators or Workstations before or during the warranty period shall be made by the Contractor on applicable Spare Parts at no cost to SEPTA. Where appropriate all parts shall be packaged for long-term and/or protected storage.

The contractor shall also provide an electronically controlled recording medium such as a database or spreadsheet where all parts and materials are listed by name, contractor part number, supplier part number, and quantities. A full record of deliveries and extractions from stock shall also be recorded within the medium as parts and materials are delivered or used.

All Spare Parts and other hardware, material and equipment not required for installation, shall be shipped freight prepaid to:

SEPTA Wheatsheaf Facility
2045 Wheatsheaf Lane
Philadelphia, PA 19124

The Contractor shall be responsible for making all arrangements for delivery of all Contract material at its own expense. Every shipment of materials, Spare Parts, etc. shall have a fully itemized packing slip detailing all contents by quantity, name, part number, etc.

1.2.14 Technical Support

The Contractor shall provide full technical support for the Training Simulators and all of its components, including Spare Parts and Peripherals for a two-year warranty period. The Contractor shall supply and install all software upgrades relevant to the Training Simulator for the two-year warranty period. The software upgrades shall include minor modifications such as trackage, signage, catenary, third rail, interlockings, cab signals, cab signaling system functions, switch, and signal locations. These modifications will maintain the CGI Imagery presented to the Trainee, thereby providing the means for SEPTA to maintain the Training Simulator environment and preserve perpetual compliance as a “Type II Simulator” as prescribed in 49 CFR Part 240.

At the close of the two-year warranty period the Training Simulator and its components and peripherals shall be functioning correctly with all the appropriate upgrades installed.

1.3 DEVELOPMENT

The apparatus and materials shall embody recommended practice, actual experience, compatibility of parts, and shall be of the latest service-tested and service-proven developments that can be incorporated without delaying delivery of the Training Simulator, unless such delay is approved.

1.3.1 Coordination

The Contractor shall be responsible for system design of the entire Training Simulator and all of its associated equipment. The Contractor shall be responsible to SEPTA for proper interrelation, function, and system integration of all aspects of the Training Simulator.

1.3.2 Relevant Experience Requirements

Relevant experience with the design and construction of rail equipment Training Simulators, and especially previous experience with the statutory requirements and industry standards which apply to the design and operation of Training Simulator equipment in the United States is required. The Contractor must have had previous exposure to the standards of the Federal Railroad Administration including those listed in 49 CFR Part 240.

The Contractor shall have a minimum of five (5) years' experience in the manufacture of Training Simulators for railroads under FRA oversight in the United States. The Contractor shall certify the Training Simulators supplied have been in continuous use for a period of not less than five (5) years. The Contractor shall provide references of at least three (3) locations where it has supplied locomotive cab Training Simulators that are compliant as defined in 49 CFR Part 240. References shall including type of simulator, duration of service, and contact information.

1.4 PROJECT IMPLEMENTATION

1.4.1 Submittals

All submittals shall become the property of SEPTA. All submittals shall be made solely by the Contractor through the use of written correspondence describing the purpose of the submittal, the anticipated work and response by the Engineer, and the specific identification of the material submitted in terms of drawing/revision numbers, document numbers, etc.

All written communications and submittals unless otherwise noted shall be typed copy on 8.5 inches wide by 11 inches high paper. Hard copy documents shall be appropriately bound to preclude lost pages while allowing ease of use without special preparation by the Engineer. Documents that can be classified as manuals, reports, or analyses shall be fastened on the left side into a profile binder to allow convenient filing. The title of such documents shall appear on the front cover, and shall appear on the spine of the binder if space permits.

Following the Notice to Proceed, the Contractor and the Engineer shall mutually agree on a common correspondence identification coding system. All correspondence shall be coded by the sender with a letter(s) from the English alphabet to designate the originator and with a unique sequence number to ensure unmistaken identity. All correspondence shall readily display the SEPTA purchase order number,

denote if a reply is required, and the identity of coded correspondence being replied to if any. Both parties shall maintain a log to list the date a correspondence is sent and received.

The documentation methodology, particularly as regards to the submission of drawing and engineering changes, shall be user-friendly and allow for ease of comprehension and review to the Engineer's satisfaction. The Contractor shall organize the submissions in a logical, interrelated fashion such that functionally or physically associated subjects are submitted in concert.

All official correspondence shall be submitted electronically in PDF form at a minimum. Information presented by the Contractor for presentations or design review meetings shall be in printed form at which time the Contractor shall supply a sufficient amount of copies for expected attendance plus one (1) copy in electronic PDF form. The Contractor shall acknowledge that only drawings, documents, topics or other materials that have been thoroughly reviewed, considered specification compliant and/or are supported by the Contractor shall be communicated to the Engineer to promote concentrated efforts on issues that will benefit and progress the program. To this end, all correspondence shall be retained for a minimum of five (5) years to reduce, if not prevent, the needless repeating of work already completed.

Should the Contractor's documentation, drawings and schedules be inadequate in the opinion of the Engineer, the Engineer reserves the right to require the Contractor to supply the necessary additional documentation, drawings, details and schedules.

After the production baseline has been achieved, engineering or manufacturing change orders or deviations shall be submitted to the Engineer for approval as they are issued. The Engineer or the Engineer’s representative(s) shall authorize the Contractor to proceed upon the written approval of drawings provided that the Contractor has notified the Engineer of all deviations. Engineer approval, however, will not relieve the Contractor of his responsibility to fulfill their contractual obligations. The Engineer will supply written reasons and explanations for disapproval of any required submittals.

Drawings and technical data submittals provided by the Contractor shall be in sequential order consistent with the schedule developed in the Design Review between the Contractor and the Engineer.

1.4.2 Language

All written communications, submittals, reports, drawings, correspondence and oral communications to the Engineer shall be made in the English language, using technical terminology conventional to that used in the North American transit industry.

1.4.3 Dimensions

All drawings generated in English dimensions need not have metric equivalents. The Contractor shall provide both metric and English dimensioning for the drawings and other communications which are either generated in or use metric dimensions. Fractional measurements shall be expressed as a decimal value and unless otherwise noted and approved drawings shall be made using third angle projections. First angle projection shall be allowed provided all views are labeled, including the front, top, bottom

and side views. Within a subsystem, all dimensions shall be given in English or English plus metric. There shall be no mixing of dimension systems on a drawing.

1.4.4 Documents

A standard format shall be used for documentation that is carried throughout the duration of the Contract.

Each document shall, as a minimum, contain the following:

- A title page with a clear and concise title block which includes all pertinent references to the Contract and an accurate description of enclosed information.
- Approval signatures of the original document on the title page to serve as an easy reminder of the approval signatures required for all future revisions.
- The SEPTA purchase order number on the title page.
- The originating company's name and address on the title page.
- The overall revision level on the title page and display the varying revision level on each consecutive page.
- The unique document number on each page of the document.
- A record of the specific changes of a revision on a dedicated page that includes space for new approval signatures for that revision without requiring the removal of previous approval signatures.
- The revision levels of individual pages on a dedicated page for verification of proper document composition.
- A table of contents and an itemized listing of tables and figures.

Depending on the type document involved, additional provisions are stipulated in the applicable Section.

Information in the form of foldouts shall not be used. Where information cannot be reduced to the required format size while maintaining legibility of important detail, it shall be divided or formatted appropriately to allow consistent and organized presentations. Except where voluminous information is involved, only one (1) side of the paper shall be used. The use of both sides of the paper shall be restricted to text which allows graphical presentations to stand alone.

As a whole, all documents shall be organized in the order of the following general segments to allow immediate recognition of information as it pertains to the Contract and to this Specification:

- A statement of the purpose of the document, and its relationship to this Specification.

- A summary, if applicable, of results and/or derived conclusions related to each individual provision where more than one (1) is involved.

- Discussion, if applicable, of background information, assumptions, and other factors necessary for the understanding of the information provided in the summary or in the body of information that follows when a summary does not apply.

- The body of the document which contains the major and usually more extensive information that supports the summary or details the topics concerned.

- All appendices providing either background information or a convenient collection of worksheets, drawings, and other reference material.

1.5 ENGINEER APPROVAL

1.5.1 General

During the course of the project, the Contractor will be submitting a significant number of items for the Engineer's approval as required by the Contract and Specifications, ranging from drawings and procedures to hardware samples. The "Engineer" is defined as being a SEPTA entity which is primarily the SEPTA Project Manager and/or the Project Manager's designee. The Contractor shall not interpret this process to mean that the Engineer will function as an arm of the Contractor's Project Management or engineering staff.

Submissions shall be structured to clearly show how the Contractor is responding to the requirements of this Specification and not on the basis of requiring the Engineer to discover how the Contractor is not meeting those requirements.

All material being submitted shall have been reviewed by qualified Contractor personnel and judged to be suitable for submission prior to doing so. This shall be so stated in the letter of transmission or on the document particularly with regards material passed through from subcontractors. Test results shall receive Contractor staff review and signature prior to submission. Submissions found to be deficient with regard to any of the above shall be immediately returned without review to the Contractor.

Submissions shall contain sufficient detail to confirm that Specification requirements are being met. However, the Contractor shall use judgment as to what level is appropriate and shall communicate with the Engineer when guidance is needed on a case by case basis. Documents with levels of detail and information considered to be beyond what is needed to confirm compliance shall be given cursory review by the Engineer and considered as background information and shall not receive formal approval. Individual submissions shall not contain material from multiple subsystems or subcontractors, and such submissions will be returned without review to the Contractor.

Submittals requiring the Engineer's approval prior to implementation shall be reviewed and classified by the Engineer as follows:

Classification	**Interpretation**
(A) Approved	The Engineer concurs with the information in its submitted form. The material may be incorporated into the program. An approval shall not be construed as: a) Permitting any departure from the Contract requirements or b) Relieving the Contractor of the responsibility for any error including details, dimensions, materials and calculations.
(B) Conditional	The Engineer conditionally agrees with the submitted information in principle, but insufficient information was provided to allow a complete review, or some details must be revised to make the information fully approved. *The material must be resubmitted in revised form for Engineer approval.*
(C) Disapproved	The Engineer does not concur with vital details. The Contractor shall not incorporate the material into the program. *The Engineer's objections must be reconciled and the material must be resubmitted in revised form for Engineer approval.*
(D) Insufficient Information	The Engineer does not concur due to lack of vital details. The Contractor shall not incorporate the material into the program. *The Engineer's objections must be reconciled and the material must be resubmitted in revised form for Engineer approval.*
(E) Information Only	Additional information that does not require approval, as determined by the Engineer.

Classification by the Engineer will be assigned within 30 days from the day the submittal is received based on a rate of submittal that is reflective of the pace of an orderly, properly managed program. Priorities will be given to special cases when possible. However, the Contractor shall consider the 30 day criteria and the time requirements involved for mailing when scheduling submittals. The days used by the Engineer in Design Review meetings or in travel to or from such meetings shall not be included in the 30 day figure. Submittals identified as being associated to evaluation phases of the assembly shall be governed by the duration of the phase itself and not the 30 day period.

1.5.2 Rescission of Status

SEPTA reserves the right to rescind prior approval or the conditional status of drawings, documents, or software if later it is discovered they do not meet the requirements of this Specification or the design is not compliant with its intended application.

1.6 DESIGN REVIEW PROGRAM

1.6.1 General

The Design Review Program is a design development and approval program which shall begin with a Concept Design Phase (CDP) and progress through a Detail Design Phase (DDP).

The Design Review Program shall include, but not be limited to, Engineer review and approval of all design concepts of the Training Simulator, all the engineering drawings, performance calculations, configuration drawings and design details, test procedures and reports, and publications.

Design Review activities shall also include review and approval of substitute or equal materials not dealt with in the pre-proposal period, and review and approval of the Contractor's test program and Quality Assurance program as well as all other Contractor management programs.

Design Review activities shall continue throughout the entire pre-production period, with each succeeding stage presenting greater amounts of detail and reflecting the progress of the designs. In addition to their own designs, the Contractor shall submit the design of all components being purchased by the Contractor for review and discussion at the Design Review sessions. In all submissions and at all sessions the Contractor and Supplier presentations shall be organized so as to show exactly how the design meets each specific requirements of this Specification.

This program must be completed and all appropriate drawings (entire Training Simulator design) approved by the Engineer prior to the delivery of hardware. Loss resulting from deviations from this principle is the responsibility of the Contractor. The approval of individual releases does not automatically entitle the Contractor to procure hardware.

Within this section, references to "Training Simulators" is meant to include any workstation within the complete training simulator network environment, such as Instructor’s Workstations, Training Simulator Workstations, Scenario Development Workstation, etc.

1.6.2 Conduct of Conferences

The Engineer shall select the location for the Design Review meetings which will in general be held in Philadelphia until completion of the Final Design Review and perhaps at the Contractor's facility from that point on at the discretion of the Engineer. The Contractor shall provide SEPTA with at least 21 days’ notice prior to any meetings or as otherwise agreed.

All reports, correspondence, and oral and written communication shall be presented in English. If in the opinion of the Engineer the proficiency of the Contractor's representatives in communicating in the English language is insufficient for efficient exchange of information the Contractor shall provide a technical interpreter to remedy this situation to the satisfaction of the Engineer at the Contractor's expense.

The responsibility for taking notes at meetings and conferences between the Contractor, Engineer and other participating parties in connection with the design, construction, and testing of the Training Simulator shall rest with the Contractor. The Contractor, after completion of any conference or meeting, will prepare and distribute within 20 days a Memorandum of Conference (MOC) which clearly and concisely details the subject matter and the conclusions reached at the conference. The Engineer shall offer written concurrence or suggested corrections within 20 days after receipt of the MOC.

1.6.3 Specification Review Conference

In order to ensure that the Contractor fully understands the detailed intent of the Contract Documents in all areas, the Contractor shall arrange for a series of meetings to be held within ten (10) days after the Notice to Proceed. These meetings shall be held at the offices of SEPTA in Philadelphia and shall be attended by representatives of the Contractor, major subcontractors, and SEPTA. At these meetings, the entire technical portion of the Contract documents shall be reviewed in depth in such a manner as to leave no doubt as to the intent of this Specification in each and every area of design, construction and testing of the Training Simulators. Memorandum of Conference will be prepared by the Contractor covering the meetings which will include each and every understanding and agreement reached and item discussed. After concurrence by all parties, the Memorandum of Conference shall become a guiding document in any areas of the Contract Documents where the intent may not be fully clear. No change shall be made to any provision of the Contract during these meetings.

Following the conference, the Contractor's Project Manager, Project Engineer, and key staff shall undergo a familiarization program on the SEPTA City Transit Division to be conducted by SEPTA personnel. The familiarization program shall not exceed three (3) days. Each individual will be given complete tours on the physical plant, rolling stock, Control Center, training facilities, and operational characteristics. The Contractor shall arrange informal nightly meetings to discuss findings during the training.

1.6.4 Design Review Phase Schedule

Within twenty (20) days after the Specification Review Conference, the Contractor shall submit to the Engineer for its approval an outline of the proposed schedule for the entire Design Review Program. **[CDRL 1-02]** All activities comprising this program shall be listed and detailed giving anticipated start and completion dates. The Contractor shall also submit a prospective schedule for all Design Review Meetings. These activities shall be arranged in, but not limited to, the following two (2) groupings:

- Concept Design Phase
- Detail Design Phase

1.6.5 Not Used

1.6.6 Design Development Process

1.6.6.1 General

The design development process shall be conducted incrementally to evaluate the progress and specification compliance of the selected design approaches and their compatibility with the performance and other requirements of the Technical Specification. Submissions shall be in a format that clearly informs or illustrates how the specification requirements are being met.

Submissions which are judged to give evidence of unsatisfactory design, random or haphazard assembly, or require the Engineer to discover what the Contractor is doing will be returned to the Contractor as disapproved.

The Contractor shall plan the Design Development process in two phases. The initial phase will be designated the Concept Design Phase (CDP) and shall be a period during which the Contractor establishes all the basic physical and systems configurations of the Training Simulators in general arrangement drawing form. Other forms of documentation may accompany these drawings. CDP shall be followed by a Detail Design Phase (DDP) during which the Contractor shall develop all detailed working drawings and documents required for the manufacture of the Training Simulators.

At any point during the contract including the design phases where the Contractor or a Supplier proposes deviations from the requirements found within the Technical Specification, they must be approved via SCR/SAR processes (as applicable) found in Section 1.9.1.

1.6.6.2 Concept Design Phase

During the Concept Design Phase (CDP) the Contractor shall prepare and issue to the Engineer as advance information a complete series of CDP arrangement drawings of the proposed Training Simulator designs a minimum of fourteen (14) days prior to the first review meeting, which shall be the subject of the first series of Design Review meetings.

CDP submittals and activities shall comprise but are not limited to the following:

<u>Schedule</u> - A schedule for all distinct releases covering the design of all areas of the Training Simulators in conformance with the Contractor's Configuration Management Plan shall be prepared at the start of the CDP and submitted to the Engineer for approval.

<u>Arrangement Drawings and Related Documents</u> - During CDP, arrangement drawings and related documents of the Training Simulators and Workstations and all major subsystem hardware items as described above shall be submitted to the Engineer for review and approval **[CDRL 1-03]**. Formal approval for the arrangement drawings shall be achieved during the CDP phase.

Drawings shall show at a minimum:

- Overall dimensions, general arrangement, and orientation.
- Location of all access doors and covers in relation to any enclosed equipment.
- Required space for opening of all doors and access doors.
- Location and space requirements for ventilation openings and cable entrances.
- Location and space requirement for all major equipment.

These drawings shall be reissued by the Contractor upon any change to show the current configurations of the Training Simulators and related equipment and allow the Contractor and the Engineer to have immediately at hand the latest general arrangements of each Workstation.

<u>Supplier Identification</u> – The Contractor shall make a complete list identifying each major supplier and their product proposed for use within the Training Simulator. The suppliers of all system and major components shall be identified as to their scope of work and products to be supplied. Along with this, a listing of names and addresses of other users of similar equipment from that supplier, including the two most recent customers, shall be submitted to the Engineer.

The Contractor shall be responsible for integration of the suppliers' schedule into the Master Schedule and assure that all changes in status or revision are maintained.

1.6.6.3 Detail Design Phase

After the CDP has been progressed to the satisfaction of the Engineer, a Detail Design Phase (DDP) shall be undertaken by the Contractor during which it develops detailed working drawings and functional descriptions for all areas of the Training Simulators based on design arrangements defined during the CDP.

All of this documentation must be created or obtained in accordance with an approved release schedule and an approved Configuration Management Plan (Section 1.11.1) and formally submitted to the Engineer for approval. Only approved documents shall have the status of official working documents from which procurements can be made. DDP submittals and activities shall comprise but are not limited to the following:

a) The continuation and updating of all activities specified as ongoing in the CDP, i.e., Master Schedule, Arrangement Drawings, and Supplier Identification.

b) Detailed Drawings and Documents - The Contractor shall submit as a minimum the following detailed drawings and related documents to the Engineer for review and approval **[CDRL 1-04]**:

   1. All top and associated sublevel release drawings, properly dimensioned, detailed, to scale, and in accordance with the approved drawing schedule.

   2. Single line control schematic and functional block diagrams for each simulator and Workstation, and electrical wiring diagrams and schematics for all electrical circuits. All test points shall be displayed. The functional block diagrams shall identify the "normal" functional paths as well as the functional paths made available through cutouts, bypasses, and redundant circuits.

   3. A complete list of controls and indicators present on all Training Simulator Workstations. Control and indicator lists shall at a minimum include representation (i.e. physical control or touch screen), simulated state (i.e. active-wired or inactive), type (i.e. push button, illuminated push button, rocker switch, indicator, etc.), color, and labeling. Locational diagrams with references to the controls and indicators lists shall also be provided.

   4. Manufacturer's data and specification sheets on all control items.

   5. Maintenance requirements and necessary procedures for all equipment in each subsystem. These shall be listed from periodic inspection to complete overhaul, with frequency and time needed to service being tabulated.

Master Test Plan – A master test plan shall be submitted that shall identify all testing by both the Contractor and/or Suppliers as required in TS 4. The test plan shall identify each test by name, system, location, revision, submittal reference, and approval status. All projected target dates for testing shall be included. The test plan shall be used to status the development of the tests.

<u>Publications and Training Plan</u> – A comprehensive publications and training plan shall be developed and submitted that reflects the collecting of technical documentation and training programs as information becomes approved under the requirement that all both publications and training must be ready prior to the delivery of the Training Simulator. The plan shall include a schedule that will allow for development of the publications and how they will be used in conjunction with training course outlines. Focus shall be placed upon Operations training, Authoring software training, and maintenance training. The plan shall also include the development and publication of a parts list. **[CDRL 1-05]**

1.7 TRAINING SIMULATOR PRODUCTION

Following the successful completion of all design review activities, the Contractor shall begin production of the Training Simulators. Each type of Training Simulator shall be assembled based on design proposals, drawings previously approved during the design phases and the assembly drawings submitted for evaluation.

The Contractor shall closely coordinate with SEPTA to assure a thorough review of the Training Simulator assembly is achieved using the proposed assembly drawings. Any discrepancy found during the assembly shall be investigated to discover its root cause and appropriate action will be taken to remedy the problem. Issues discovered shall be identified as either Quality or Engineering related. Engineering related issues shall be defined as items in need of change due to fit, form, function, materials, circuitry or software changes where the configuration of the Training Simulator will change as shown in drawings, schematics or software revision levels. Those deemed as Quality issues shall be tracked and monitored within a separate list, investigated for root cause and quickly corrected during the assembly phase.

Any Specification issues found that may result in an exception or change of the requirements found within shall be handled via the Change process as described in TS 1.9.

All production related testing and additional pre-delivery testing as required TS 4 shall be fully pretested during the assembly prior to the Training Simulator FAI. Any changes resulting from testing such as circuit changes, software or test procedural changes shall be made prior to official FAI testing to allow conformation of changes effectiveness. FAI testing shall occur concurrently with Factory Acceptance testing.

1.7.1 Training Simulator and Workstation First Article Inspection

Each type of Training Simulator and Workstation shall undergo a First Article Inspection consisting of a pre-FAI audit, physical inspection, and pre-delivery testing. These activities shall occur at the Contractor's facility.

This formal examination shall be gauged against the production drawings, pre-delivery test results, Specification, and Design Review minutes developed during the design and assembly process.

30 days prior to the inspections, the Contractor shall submit to the Engineer an engineering data package for each type of Training Simulator or Workstation in sufficient detail to allow the Engineer to compare physical attributes of the Training Simulators with the engineering documents which describe it. **[CDRL 1-06]** This package shall serve to clarify any discrepancies between the design drawings and documents and the manufacturing process.

SEPTA reserves the right to postpone any Training Simulator or Workstation FAI until the engineering data package has met SEPTA's satisfaction.

Upon satisfactory completion of the pre-FAI audit and physical inspection of the Training Simulator, any objectionable issues found either in the physical configuration or that of operation due to circuitry or software shall be recorded and corrective action(s) resulting in changes in drawings, schematics and/or software shall be committed to in writing. Such drawings or schematics that are pending change shall be highlighted in the master drawing schedule until completion of the change is completed and approved by SEPTA.

Upon the completion of a Training Simulator FAI or Workstation FAI at the Contractor's facility, and with the update of any addendums, test result open issues, SEPTA shall determine the status of the Training Simulator or Workstation. Successful completion of this first inspection process will provide the Contractor with provisional approval of the Training Simulator's design and assembly level drawings pending any further changes due to post-delivery on-site testing.

The Contractor shall assume the full responsibility, risk, and expense for any procurement or manufacturing action initiated prior to receipt of the Engineer's approval, and for any subsequent changes made resulting from verifying the Training Simulators' capability to meet the requirements of this Specification during post-delivery on-site testing.

1.7.2 Pre-Shipment Inspection

The Engineer will assign a Field Representative to perform a Pre-Shipment Inspection upon the completion of each Training Simulator or Workstation using a printed inspection form. The Contractor shall arrange the schedule for shipment of each Training Simulator to provide a minimum of one (1) day for inspection of the Training Simulator or Workstation after it is fully completed and has had a comprehensive final inspection performed by the Contractor's Quality Control. All Pre-Shipment tests must have been completed and accepted. All Contractor QC inspection discrepancies must be reworked and complete and the Training Simulator or Workstation is judged ready for shipment. The Engineer shall be given notice of an upcoming Pre-Shipment Inspection at least twenty-one (21) days before its schedule date.

Prior to the Pre-Shipment inspection the Contractor shall present the following items **[CDRL 1-07]**:

a) Copies of all Contractor Final Inspections/Tests - At the time the Training Simulator is presented to SEPTA for the Pre-Shipment inspection, a representative of the Contractor's Quality Department must present to the Field Representative a copy of the total final inspection performed by the Contractor's QC. All discrepancies must be signed off as acceptable thus denoting the re-inspection and associated rework has been found acceptable. In addition to the inspection one copy of each pre-delivery test, signed as being accepted by an authorized SEPTA Field Representative shall be submitted.

b) A full configuration as-built status report reflecting the level of build for the individual Training Simulator including all revision levels which have been implemented and a full accounting of those yet to be installed.

A pre-delivery inspection shall be performed on each completed Training Simulator or Workstation. Inspection results shall be logged on inspection forms mentioned above and submitted to the Contractor for rework/disposition. After the rework has been completed each item will be inspected by the Contractor's QC. When the discrepancy list has been totally reworked, the Training Simulator or Workstation can then be offered again to the Field Representative for re-inspection. Inspection data and status updates shall be performed by the Contractor.

1.7.3 Shipment Authorization

When the Pre-Shipment Inspection specified in Section 1.7.2 has been concluded to the satisfaction of the Engineer or the Engineer's Representative, and any defects discovered are fully corrected, the Contractor shall present a release for shipment authorization document to the Engineer or the Engineer's Representative for the purpose of obtaining SEPTA's authorization to ship. **[CDRL 1-08]**: No shipment of Training Simulators or Workstations or other completed material shall be made by the Contractor to SEPTA without such a document. Shipment of any Training Simulator or Workstation without a SEPTA authorized release for shipment document may result in the refusal of delivery on SEPTA's property.

Neither a Pre-Shipment Inspection nor a release for shipment will be considered by the Contractor to constitute acceptance of a Training Simulator, Workstation, or other material. The Contractor shall prepare each Training Simulator or Workstation for shipment in such a way as to allow it to be placed in service immediately upon arrival following removal of any necessary shipping devices and installation of any removed parts. Any parts removed for shipment or other necessary special equipment needed for shipment shall accompany each Training Simulator.

All Training Simulators, Workstations or other material shall be properly packaged or otherwise prepared for any shipment to insure that no damage will take place.

1.7.4 Training Simulator Commissioning

Upon arrival at SEPTA, the Training Simulator shall be visually inspected for shipping damage. After visual inspections and installation has been completed, full Acceptance Commissioning Tests shall be performed on the Training Simulator as outlined in TS 4.

1.8 DRAWINGS

1.8.1 Arrangement Drawings

Upon the completion of Design Review establishing the concepts of the Training Simulator design, the Contractor shall submit finished arrangement drawings to the Engineer for approval prior to the start of fabrication of parts for the Training Simulator.

The Contractor shall be responsible for providing drawings used within the configuration and design of the Training Simulator. The drawings shall include all installation and connection drawings. Also included shall be general arrangement drawings, color schedules and clearance drawings. Each drawing shall include a bill of materials showing the drawing numbers for individual parts. For each piece of equipment on the Training Simulator requiring maintenance, inspection or repair, the Contractor shall supply an interface drawing showing the details of the equipment mounting method and hardware and the access space requirements of that equipment.

It is the intent that all drawings required be submitted as outlined in the design phases, with a full set culminating prior to the Training Simulator FAI in a PDF softcopy formats (softcopy at a minimum, additional hard copies as requested).

Any and all changes that result in a drawing change after an FAI must be submitted to SEPTA for approval prior to implementation.

1.8.2 Schematic Drawings and Documents

The Contractor shall furnish SEPTA with complete circuit and integrated schematic diagrams, with the exception of commercial off the shelf equipment, including a full description of each interface with its value and voltage levels for SEPTA's use in maintenance and repair of the Training Simulators. Circuit and integrated schematic diagrams will be accompanied by a complete device table and point-to-point wiring list. A narrative shall be included to instruct the user in the use of the documents.

Appropriate test parameters and troubleshooting instructions shall also be furnished for each assembly and sub-assembly. This information shall be provided in maintenance manuals and training guides.

This document shall consist of a wire point to point listing along with integrated connection diagrams. Each wire, except for those totally within self-contained devices, shall have a complete description of its physical characteristics, terminations, labeling and routing. The connection diagrams shall show all cable and wire raceways, conduits, junction boxes and connection points.

All of these documents shall have a complete index. An appendix to each document shall contain a listing of all field modifications made to each Training Simulator, including a brief description of the modification, type of simulator affected, dates started and completed, and which party performed the work (Contractor or Supplier). When all warranty and modification work is completed at the end of the Contract, the Contractor shall fully update these documents and supply two (2) copies of each, all in approved heavy-duty plastic binders and identified as final versions, to the Engineer. All of the above documents are to be considered as entities separate from any similar documents required by TS 5. **[CDRL 1-09]**

1.9 CHANGES

1.9.1 Technical Specification Changes

During the Design Review Process discussions may arise where specific Technical Specifications are not being met, however the Contractor feels the spirit of the specification could be made using alternate means or materials. If during the course of these discussions, SEPTA indicates they will entertain the possibility of change, the Contractor shall be allowed to submit an SCR or SAR, whichever is applicable, for approval:

<u>Specification Change Request (SCR)</u> - SCRs are used in the event when specific changes are made to requirements that extend throughout the Technical Specification.

<u>Specification Adjustment Request (SAR)</u> - SARs are used when the change is limited to a particular instance only and does not change the basic requirement used throughout the Technical Specification.

The formats for both SCR and SAR proposals shall contain the following information:

- The specific Technical Specification requirement to be changed (in text form)
- Alternate Specification wording for the proposal (SCR) or descriptive instance of the item to be changed (SAR)
- Justification for the proposal
- Technical information attachments as applicable

- Identification of all applicable drawings to be affected by the change.
- Cost or schedule impact

During the Design Review Process, the Contractor shall submit to the Engineer a continually updated list of manufacturing, supplier, interconnection and assembly drawings that would be affected by such changes. Any Specification changes after the Training Simulator FAI, the changes must be submitted via the Engineering Change process in TS 1.9.3 if a controlled document such as a drawing, software, or procedure is affected.

1.9.2 Changes to Drawings, Controlled Documents and Software

The Specification, Design Review MOC's, in addition to approved drawings, software and test procedures, identifies the procurement baseline for the Training Simulator. **[CDRL 1-10]** Once the baseline has been set and agreed to by SEPTA, all changes to the procurement baseline shall be documented by a change to the controlling document which reflects the baseline requirement in the form of drawings, procedures or software revision levels.

Any and all changes that result in a drawing, software or operational change after a Training Simulator or Workstation FAI, the change must be submitted to SEPTA for approval prior to implementation.
The processing of these changes shall be performed in accordance with the procedures described Section 1.9.3. All changes shall be reviewed by the Contractor's department responsible for configuration control prior to submittal to the Engineer for review and approval.

1.9.3 Engineering Changes

Prior to the setting of the production baseline, the Contractor shall control and maintain an engineering change process that will enable all changes are made to drawings, software and other controlled documents so they reflect the most up to date revisions.

After a Training Simulator or Workstation FAI where the production baseline has been set and agreed to, All technical changes shall be proposed in the form of a written correspondence to SEPTA, which shall be submitted to the Engineer for approval prior to starting any implementation.

In addition to the revised drawing or procedure, the correspondence shall also contain the full details, instructions, tool list for post-production changes, parts list, procedures, and drawings necessary for the performance of the work, shall reference all software (publications, drawings, training program, etc.) which must be changed giving the revised information, and also describe any needed revisions or modifications for interim use.

Any action or cost necessary to correct problems in the product or documentation arising from the Contractor's misclassification shall be borne by the Contractor. The Contractor shall also be responsible for controlling changes originating from their suppliers. The Contractor shall submit the correspondence to the Engineer accompanied by the technical documentation and the cost information necessary to fully evaluate and approve the change. The correspondence shall describe changes to the Specification when applicable with the inclusion of an approved SCR or SAR as described in Section 1.9.1.

All technical changes that affect safety shall be immediately reported by the Contractor to the Engineer by fax, e-mail, telephone, express mail, in person or by other expeditious means. Technical changes that affect operation shall also be expedited.

The Contractor shall identify and track the change, and if reported verbally shall confirm the change in writing to the Engineer within two (2) days. All documents shall be submitted to the Engineer in writing accompanied by all technical information and proposed changes. Any change not performed on every Training Simulator or Workstation must include supporting rationale and shall be subject to the Engineer's approval.

1.9.4 Accountability

The Contractor shall maintain records such that the configuration of any item being delivered shall be definable in terms of its component part numbers. Differences between the as-built configuration and the release records and documentation shall be known and accounted for, and the status of change approvals and incorporations shall be known and recorded at any point in product development, test, production, or operational usage.

A serialization and configuration control record shall be maintained by the Contractor for each Training Simulator or Workstation. The Contractor shall make every effort to incorporate changes at the Contractor's facility prior to shipment. A full configuration report must be delivered to the SEPTA prior to any shipment.

If any changes are deemed impossible to complete based on material concerns, SEPTA at its discretion, may allow shipment with the change as a shipment exception. If the shipment exception is authorized, the Contractor will need to provide information for plans for the change to be retrofitted after delivery or be scheduled in a recognized retrofit campaign agreed to by SEPTA. **[CDRL 1-11]**

The Contractor shall maintain an effective system to track all changes. All retrofit changes shall be recorded on a basis as to the Training Simulator or Workstation they were installed in a controlled manner.

1.10 PROGRAM MANAGEMENT

The Contractor shall submit to the Engineer for approval within thirty (30) days after the Notice to Proceed a Program Management Plan. **[CDRL 1-12]** It shall contain as a minimum an organizational chart providing a definition of personnel responsibilities, the methods and communications to be used to control the program (its schedule, technical performance, program changes, subcontracts, material procurement and field engineering support) and details concerning the scheduling plan for the contract work, as described below.

The Contractor shall organize the conduct of the project in an effective manner. At a minimum there shall be a Project Manager and a Project Engineer as primary staff. The Contractor shall propose selections for approval from a group having considerable pertinent experience in work of the type involved. This primary staff shall have full authority from the Contractor's higher management to make the final commercial and technical decisions and commitments for this procurement.

The Program Management plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in Section 1.10.1. Changes will be subject to approval by the Engineer. Lack of notification or changes deemed compromising the intent of the Technical Specification shall be cause to revoke the approval status of the plan.

1.10.1 Monthly Progress Reports

The Contractor shall submit to the Engineer a Monthly Progress Status Report. **[CDRL 1-13]** In the Report, the Contractor shall state the percentage of work physically completed and include a description of the physical progress during the report period; plans for the forthcoming report period; problem areas, current and anticipated; delaying factors and their impact; and an explanation of corrective actions taken or proposed. Specifically addressed in the report shall be the status of uncompleted activities which have less than 30 calendar days float and which are either in progress or scheduled to be started within the next reporting period. At the request of the Engineer, the Contractor shall participate in pre-update conferences to verify progress and review modifications to the detailed network schedule prior to the formal monthly submittal. This report shall also include the work done by major suppliers.

1.10.2 Audits

During the evaluation of design, the Engineer will monitor the Contractor's efforts to determine the degree to which the objectives of the Contract are being achieved through the use of reviews and audits. The reviews and audits shall be conducted jointly by the Engineer and the Contractor. In all cases, approval by the Engineer shall not constitute relief from contractual obligations.

1.10.3 Post-Delivery Changes

The Contractor shall contain within their Program Management Plan a system to identify, design, and install in every Training Simulator any modifications made necessary by defects discovered during the warranty. The Configuration Management Plan shall be a part of this effort. A monthly report shall be submitted to the Engineer identifying every defect on each Training Simulator during the previous month, its resolution and the status of each Training Simulator involved in any required retrofit, including any necessary changes to publications, drawings, or education programs.

1.11 CONFIGURATION MANAGEMENT

1.11.1 Plan

The Contractor shall develop and submit to the Engineer for approval a Configuration Management Plan within 30 days after the Notice to Proceed. The Plan shall illustrate how the Contractor intends to meet the configuration management requirements. **[CDRL 1-14]**

The Configuration Management Plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in Section 1.10.1. Changes will be subject to approval by the Engineer. Lack of notification or changes deemed compromising the intent of the Specification shall be cause to revoke the approval status of the plan.

1.11.2 Identification

The Contractor's technical documentation shall be capable of defining the approved configuration of hardware and computer software under development, test, production, or in operational use. The technical documentation shall identify the configuration to the lowest level required to ensure repeatable performance, quality, and reliability.

1.11.3 Provisions

The Contractor shall maintain accurate and current configuration records which shall be available to the Engineer throughout the period of the Contract and until the end of the warranty period. The Contractor shall ensure that their supplier's equipment incorporated in the Training Simulator design complies with all the related provisions that follow.

1.12 QUALITY ASSURANCE PROGRAM

1.12.1 Plan

The Contractor shall develop and submit to the Engineer for approval a Quality Assurance Plan for the Contractor and those of all major suppliers and suppliers at the time of the Design Review. **[CDRL 1-15]** The plan shall illustrate how the Contractor intends to meet the quality assurance requirements of this Specification and shall include as a minimum:

- Flow charts of paperwork for the acceptance or rejection of material, for identification and disposition of unacceptable items resulting from inspections, for the specific accountability of material found malfunctioning during production conformance testing and for configuration verification of the constituent items, etc.

- Forms to be used to convey, track and account for hardware design changes implemented in the Training Simulators regardless of their state of completion and any other forms necessary for the program.

The Quality Assurance Plan shall have a live document status. Any and all changes must be submitted to the Engineer during the next monthly progress report covering the time period the change took place, as referenced in TS 1.10.1. Changes affecting the project will be subject to approval by the Engineer. Lack of notification or changes deemed compromising the intent of the Technical Specification shall be cause to revoke the approval status of the plan.

1.12.2 Procedure Documents

The Contractor shall ensure that inspection and tests are based on the latest approved revision or change to drawings and specifications. A procedure shall be maintained that embraces the adequacy, completeness and updating of drawings, software, and the control of changes. This procedure shall be in coordination with the change control system as provided for in Section 1.9.3. The Contractor shall ensure that obsolete drawings, software, and procedures are promptly removed from all points of issue and use.

The Quality Assurance Plan shall ensure that there is complete compliance with Contract requirements for proposing, approving and effecting engineering changes. The Contractor's responsibility for drawings, software, and changes shall extend to the drawings, software, and changes provided by the Suppliers for the Contract.

1.12.3 First Article Inspection

The Contractor's Quality Assurance program shall include a procedure for conducting the First Article Inspection (FAI).

The FAI shall be performed using the approved baseline drawings or software versions in conjunction with this Specification reflecting specific requirements of the subject along with any special tools and/or equipment needed to verify the design requirements, configuration and operation (if applicable) of the item being inspected.

All technical data required for maintenance manuals and or parts catalogs shall be submitted as initial drafts in authoring file and PDF file formats per Section 5 prior to the full acceptance of the FAI. The initial drafts shall contain sufficient information to adequately maintain the equipment.

The Engineer shall be given notice of an upcoming FAI at least three weeks (21-days) before its schedule date.

1.13 PERFORMANCE OF THE WORK

1.13.1 Contractor's Responsibility

Performance of the work under this Contract shall be done in strict conformance with the Contract documents and consistent with the best past practices of the Contractor for the manufacture of Training Simulators and their component parts, whether or not expressly set forth herein. The Contractor alone shall at all times be responsible for the adequacy, efficiency, and sufficiency of their plant, equipment and employees and those of their suppliers, and shall have the ultimate responsibility for the methods used for the manufacturing and assembling of the items of material or equipment being furnished; and shall maintain records of all engineering changes.

To insure that ordered material meets Specification requirements, the Contractor shall forward to the Engineer a copy of all purchase orders or changes in existing purchase orders issued (with price data omitted) giving a complete bill of material description of the material ordered from any major supplier or to obtain equipment which is specifically identified in this Specification by brand or model number, or for certain components identified previously by the Engineer. **[CDRL 1-16]** All equipment specifically identified in this Specification (or its Engineer approved equal) must be so identified by brand or model number on relevant purchase orders even when it would be included within a major supplier's complete system.

The Contractor shall take full responsibility in assuring that the Purchase Orders reflect conditions where all suppliers for parts, components, and services meet the terms and requirements of this Specification in regards to design, materials, and workmanship (as applicable) in addition to ancillary items such as participation in manuals and training.

The Contractor's purchase orders shall contain a requirement for the supplier to notify and obtain approval from the Contractor of changes of design of the products which affect fit, form or function, or substitution of materials.

Whenever the Contractor or a supplier refers to a material or process by their own specification number, they shall also list the commercial equivalent. If there is no commercial equivalent, they shall provide the Engineer with copies of their own specification, which will be considered confidential in nature.

1.13.2 Design Responsibility

The Contractor shall be responsible for the detailed design of the Training Simulators, all associated software and component parts, and shall prepare all necessary drawings and schedules for the Engineer's approval prior to assembly of any items of material or equipment. Consequently, the Contractor or suppliers shall not deviate in their material or equipment purchasing from the approved drawings and schedules. SEPTA shall not be liable for any additional costs or delays caused by the Contractor's failure to secure the prior approval of the Engineer where required by the Contract Documents.

The Contractor, as part of its responsibility for system design of the entire Training Simulator and all of its equipment, shall be responsible for the proper interrelation, function and system integration of all phases of all systems, their interrelation with all other parts of the simulator, and their interrelation within the Simulator Training Facility, during the design, manufacturing, installation and testing phases of the Contract.

1.13.3 Supplier’s Duties

The Contractor shall require that each supplier of software, components, apparatus, or parts shall make, assemble, and completely test ready for installation by the Contractor the component or apparatus to be furnished by said manufacturer as per the Contractor's instructions.

The Contractor shall ensure that all Training Simulators of each type are identical in all respects except as otherwise agreed to by the Engineer. The Contractor shall ensure that all the material produced by all suppliers is in accordance with approved drawings and identical throughout the production run except as otherwise agreed in order to implement modifications and improvements which will be retrofit on earlier production.

1.13.4 Cooperation

The Contractor shall require that all suppliers and manufacturers of all materials, software, apparatus, and parts shall cooperate to the fullest extent during design, construction, and testing to insure proper use or installation of their products. The integrated performance of all equipment within the Training Simulator environment is required. The suppliers shall give prompt notice to the Contractor if the use or installation proposed by the Contractor is not satisfactory to them. No agreement with respect to the above shall be made without a conference at which the Engineer and the Contractor are each represented. The Contractor shall ensure that each major supplier is provided with an updated complete copy of these Contract Documents.

1.13.5 General Workmanship

Whenever under the Contract documents it is provided that the Contractor shall furnish materials or manufactured articles or that it shall do work for which no detailed specifications are set forth within said documents, the materials or manufactured articles shall be of the best grade in quality and workmanship obtainable within the market from firms of established good reputation or, if not ordinarily carried in stock, shall conform to the usual standards for first class materials or articles of the kind required with due consideration of the use to which they will be put. In general, the work performed shall be in full conformity and harmony with the intent to secure the best standards in the work as a whole or in part.

The work performed by the Contractor and all suppliers shall be executed in conformity with the best accepted standard practice of the trade so as to contribute to maximum efficiency of operation of the material and equipment purchased, accessibility of all parts and components, a pleasing appearance of the material and equipment, and minimum cost of maintenance.

Whenever it is necessary for whatever reason for the Contractor to modify a part used on the Training Simulator or in any spare parts following the shipment of the Training Simulators, the Contractor shall undertake a retrofit program at its own expense to modify all Simulators and spare parts as necessary so that each similar part has an identical part number, is interchangeable, requires the same troubleshooting procedures and levels of maintenance, and performs identically. The Engineer may waive this requirement on an individual case basis.

1.13.6 Defective Workmanship or Materials

Whenever the Engineer determines that any of the work being done under the Contract, or that the kind or quality of materials supplied in connection therewith, are not fully and completely in accordance with any requirement of this Specification, the Engineer shall give notice of such noncompliance to the Contractor in writing, and the Contractor shall immediately upon receipt of such notice do all things

required to remedy such noncompliance. This does not relieve the Contractor from having and enforcing its own Quality Assurance Program.

1.13.7 Furnishing of Warranty Parts

The Contractor has sole responsibility under this Contract to maintain sufficient warranty spare parts in their stock to support the warranty period requirements. SEPTA is under no obligation to provide spare parts to the Contractor for warranty purposes. The Contractor shall keep on-site at the SEPTA Simulator Training Facility, or other location on SEPTA property so designated by the Engineer, a sufficient quantity of spare parts to expedite the repair and return of the Workstations or Training Simulators to service.

In the event that the Contractor does not have needed warranty spare parts on hand, SEPTA, on an individual item basis and in kinds and amounts solely within its discretion, may permit their spare parts to be used by the Contractor in performance of warranty work. Any spare part from SEPTA's stock that is used for warranty by the Contractor shall be replaced by the Contractor with a new part of original quality to the latest configuration and with a new original warranty.

The Contractor and all of their subcontractors and suppliers must also maintain in stock in their warehouses sufficient levels routine maintenance spare parts to allow SEPTA to purchase them and have timely delivery. SEPTA shall maintain a sufficient level of maintenance parts based upon replacement schedules contained within the publications.

1.14 SPARE PARTS

All spare parts must be identified with a labeling system including at minimum the name, part number, and serial numbers where appropriate of the item. The Contractor shall provide SEPTA with a database or spreadsheet storing corresponding information and correlating it with actual part numbers if different, location of item on the Training Simulator, relevant drawing numbers on which the item appears, manuals and publications referencing it, recommended quantities vs. actual quantities on hand, expected life of the item, lead time for replacement, and sources for replacement. This database or spreadsheet shall also correlate SEPTA's part number with all recommended and available standard brand or supplier part numbers specifying company name, company part number, company location, and telephone number.

Whenever it is necessary for whatever reason for the Contractor to modify a part used within a Training Simulator or a Workstation or any Spare Parts following the shipment of the Training Simulator or Workstation, the Contractor shall undertake a retrofit program at their own expense to modify all Simulators and spare parts as necessary so that each similar part has an identical part number, is interchangeable, requires the same troubleshooting procedures and levels of maintenance, and performs identically. The Engineer may waive this requirement on an individual case basis.

Should any part become unavailable or obsolete during the warranty period, the Contractor shall be responsible for securing a compatible, equivalent and interchangeable part. Such parts are subject to the SEPTA's review and approval.

1.15 LOGISTICAL SUPPORT

A description of a Contractor-administered two (2) year plan to implement warranties and provide technical assistance and repair parts for all equipment supplied must be submitted and approved by the Engineer prior to shipment of the Training Simulators. **[CDRL 1-17]** As part of the plan, the Contractor must provide a complete listing of every supplier used to provide parts on the Training Simulator, location of supplier parts depot(s), identification of supplier personnel that SEPTA should contact to purchase spare parts or to obtain price information for all Contractor and supplier components and their related parts; and the methodology the Contractor and their suppliers will use to process and track customer orders.

The plan must also detail how the Contractor intends to implement the warranty program. This shall include the administrative control of the flow of warranty-related defective parts from SEPTA to the Contractor and repair parts return to SEPTA, the availability of those parts and components which the Contractor and his suppliers will need to support warranty without dependence on SEPTA purchased spare parts, the method of control for submittal, review and approval of SEPTA warranty claims, and payment of claims to SEPTA.

The Contractor shall furnish to the Engineer prior to delivery of the Training Simulator a list of the type and quantity of standard replacement parts and incidental hardware which SEPTA should keep in current stock, based on the Contractor's knowledge of the Training Simulator design and ordering lead times. **[CDRL 1-18]** The list shall be submitted a second time with updated information at the end of the warranty period. Both listing shall be in a format acceptable to the Engineer.

The Contractor's Service Manager, or other individual designated in writing by the Contractor, shall be given full authority to act on behalf of the Contractor and his suppliers to approve SEPTA's warranty claims as necessary for payment to SEPTA. Action on claims submitted by SEPTA's representative to the Contractor's personnel must be taken within seven (7) days of claim submittal. In the case of disputed claims, the Engineer and the Contractor shall review, negotiate, and resolve such claims on a monthly basis. Invoices for approved claims will be submitted by SEPTA on a monthly basis. Payment shall be made to SEPTA within 30 days of the receipt of the invoice by the Contractor.

1.16 DELIVERY AND ACCEPTANCE

1.16.1 Acknowledgment Of Delivery

When each shipment of equipment sent by the Contractor arrives at the designated SEPTA location, the Engineer or his representative shall examine the shipment, and issue an Acknowledgment Of Delivery document which shall state the date of actual delivery upon SEPTA property. This date shall be used in calculating the Contractor's performance against the Contract time requirements. As a courtesy the Engineer shall note any apparent damages or defects which have occurred during transit. The Contractor shall be responsible for any damages or defects to each shipment, whether noted by SEPTA or not, and shall repair any damage or defect immediately. The Acknowledgment Of Delivery does not constitute acceptance of a Training Simulator or other material or its conformance with the terms of the Contract by the Engineer.

1.16.2 Defects

If any Training Simulator, Workstation, or other material or equipment is delivered incomplete, does not meet applicable standards, contains any defective or damaged parts, or fails in any other way to meet this Specification, the Contractor shall arrange that the item be completed or deficiencies corrected, or damaged parts removed and new or repaired parts consistent with the requirements of a new item installed without any cost whatsoever to SEPTA.

1.16.3 Acceptance Commissioning And Inspections

As the Training Simulators are received, the Engineer will oversee Acceptance Commissioning Tests on each Training Simulator, as provided for in Section 4. These tests shall be performed by the Contractor or under its direction and at its expense. The Contractor shall provide all personnel necessary to monitor and record test results. SEPTA shall provide all operating personnel at its expense for these tests. All tests shall be conducted in the presence of the Engineer, and at times agreeable to SEPTA and the Engineer. Any damage or defective condition discovered during the acceptance testing shall be corrected immediately by the Contractor.

No Training Simulator or Workstation shall be accepted if it contains any defects or if not in a complete operating condition. At the option of the Engineer, a Training Simulator or Workstation which has completed Acceptance Commissioning Tests and had defects which were later corrected by the Contractor, may be required to be retested repeating some or all of the original procedure, if the Engineer has reason to believe that the original defects were of a serious nature, or if there is some questions as to the nature of the repairs.

1.16.4 Notification Of Acceptance

When acceptance inspections for items of material or equipment other than the Training Simulator have been completed, the Engineer will provide the Contractor within 10 days either a certificate of acceptance document or a rejection notice. Any and all deficiencies discovered during acceptance inspection or subsequently shall be corrected as provided in the Contract Documents. When each Training Simulator or Workstation has properly completed all acceptance commissioning tests and contains no known defects, the Engineer will promptly issue a certificate of acceptance document to the Contractor.

1.17 DEFECTIVE WORK

Should the Engineer have reasonable evidence that defective work or material has been permitted by the Contractor or a Supplier, the Contractor or Supplier shall furnish the appliances and labor for making such investigation and inspection as may be required by the Engineer in writing. Any imperfect construction or materials which may be disclosed shall be corrected promptly. During any period of time from construction to acceptance, any inadequacy of design, construction or testing or any damage by any cause whatsoever, except that caused directly by SEPTA, shall be corrected by the Contractor at no cost to SEPTA. If the investigation discloses no defects, the expense of such investigation will be borne by SEPTA, and the delay caused by such investigation will be considered as being beyond the Contractor's control.

1.18 ELECTRONIC INFORMATION CONTROL

The Contractor shall compile, store, and transfer documents via electronic files whenever possible. Official correspondence and/or technical submittals required in printed form by this specification shall be accompanied by the electronic copy of each document in a software format agreed to by the Engineer. Acrobat PDF formatted files shall be used as the standard electronic format medium for submittals and correspondence. Upon SEPTA’s request, the Contractor shall supply the originating authoring file to assist in reviews and data assessment on a case by case basis.

1.18.1 General Use Software

All general use software shall be designed to run on Microsoft Windows platform based PCs. The following software shall be used as a guideline:

Project Management Correspondence, Databases, Spreadsheets, and Presentations	Microsoft Office
Drawings, Schematics	AutoCAD 2002 compatible
PDF file creation and viewing	Adobe Acrobat
Project Scheduling	Primavera, Microsoft Project, or as approved by the Engineer

The Contractor may request the use of alternate programs in lieu of those listed for Engineer approval. However, if approved, the Contractor shall bear the cost of new software and the cost of training SEPTA personnel in Philadelphia on the use of the software.

1.18.2 Master Software List

The Contractor shall create a Master Software List showing all software to be used during the duration of the Contract. The Master Software List shall be maintained by the Contractor and shall have live-document status and consist of three basic categories:

- Commercial - This category covers over-the-counter software used in common business practices. Information shall include the authoring company name, software trade name, and revision level.

- Specialty Software - This category contains specialty software for the maintenance, testing and diagnostics of the Training Simulator as specified in Section 3. Note: Changing of revision levels will require formal notification to SEPTA.

- Equipment Related - This category includes any special software used internal to the Training Simulators operation, including but not limited to Training Simulator computer system programs and internal component programming as specified in Section 3. Note: Changing of revision levels will require formal notification to SEPTA and retrofit of all affected Training Simulators and/or components.

The preliminary Master Software List shall be submitted to the Engineer starting with the first category of commercial software to be commonly used by both the Contractor and SEPTA. **[CDRL 1-19]** The Contractor shall specifically note the revision level of all software used by the Contractor's company so they can be compared to software presently being used within SEPTA. In any instance where software

revision levels do not match, the Contractor shall provide the necessary upgrades as determined by Section 6.

As software is identified for use within a Training Simulator or Workstation, the Contractor shall add the software to the Master Software List and submit the revised list with the monthly Project Management Report. Copies of the software shall be sent for archival purposes as attachments to the electronic version of the project management report.

1.18.3 Software Upgrades

Due to the nature of ongoing software developments, it is SEPTA's desire to keep project files abreast with the latest features that correspond with the most efficient use of the documents and data during the duration of the Contract. The Master Software List shall be reviewed for potential improvements at the time of the following events. The cost of upgrading software shall be borne by the Contractor.

- Contract Start
- Delivery of the Training Simulators
- At the completion of the warranty period

The Contractor shall provide for approval by the Engineer a plan to for carrying out software upgrade campaigns. In the event software upgrades are found as being necessary by the Engineer or being introduced by the Contractor, three (3) manual sets and seven (7) sets of software copies shall be supplied to the Engineer for SEPTA use and distribution. **[CDRL 1-20]**

1.20 ABBREVIATIONS and ACRONYMS

The following abbreviations and acronyms used in this Specification shall have the meanings provided herein:

AAR	Association of American Railroads
AC	Alternating Current
ADA	Americans with Disabilities Act of 1990 (and regulations promulgated there under, including 49 CFR Parts 27, 37 and 38)
ATCS	Advanced Train Control System
ATC	Automatic Train Control
AWG	American Wire Gauge
BCP	Brake Cylinder Pressure
B&B	Bridges and Buildings
CAD	Computer Aided Drafting
CBT	Computer Based Training
CBTC	Communication Based Train Control
CCTV	Closed Circuit Television
CDP	Concept Design Phase
CDRL	Contract Deliverable
CFR	Code of Federal Regulations
CGI	Computer Generated Imagery
CPU	Central Processing Unit
CTD	City Transit Division
C&S	Communications and Signals
dB	Decibel
dBA	Decibel, "A"- Weighted Scale
DC	Direct Current
DDP	Detail Design Phase
DOS	Disc Operating System
DOT	United States Department of Transportation
EEPROM	Erasable, Programmable, Read-Only Memory
EIA	Electronic Industries Association
EMD	Electromotive Division, General Motors Corporation
EMC	Electro-magnetic Compatibility
EMI	Electro-magnetic Interference
EMU	Electric Multiple Unit
EP	Electro-pneumatic
ET	Electric Traction
F	Fahrenheit
FAI	First Article Inspection

FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GE	General Electric Co.
GFI	Ground Fault Interrupter
GP	General Purpose
HVAC	Heating, Ventilation and Air Conditioning
Hz	Hertz
IC	Integrated Circuit
I/C	Intercom
IEEE	Institute of Electrical and Electronic Engineers
I/O	Input/Output
ISO	Organization for Standardization
KPH	Kilometers per Hours
kV	Kilovolts
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LRV	Light Rail Vehicle
MAS	Maximum Authorized Speed
MHZ	Megahertz
MIL	Military Specification
MMI	Man-Machine Interface
MOC	Minutes of Conference
MOW	Maintenance of Way
MPH	Miles per Hour
MS	Military Standards
MTBF	Time between Failures
N/A	Not Applicable
NBS	Bureau of Standards
NEC	Northeast Corridor
NESC	National Electrical Safety Code
NEMA	Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
OSHA	U.S. Occupational Safety and Health Administration
PA	Public Address
PA/IC	Public Address and Intercom
PC	Personal Computer
PCMCIA	Personal Computer Memory Card International Association

ppm	Parts Per Million
PROM	Programmable Read Only Memory
psi	Pounds Per Square Inch
psig	Pounds Per Square Inch Gage
PSR	Permanent Speed Restriction
PTS	Positive Train Stop
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RMS	Root Mean Square
SAR	Specification Adjustment Request
SCR	Specification Change Request
SDD	Software Design Description
SEPTA	Southeastern Pennsylvania Transportation Authority
SFE	SEPTA-Furnished Equipment
SMMS	SEPTA Material Management System
SSP	System Safety Program
TBD	To Be Determined
TSR	Temporary Speed Restriction
UPS	Uninterruptible Power Supply
USASI	United States of America Standards Institute
UV	Ultra Violet
VAC	Volts Alternating Current
VETAG	Vehicle Tagging System
VDC	Volts Direct Current
VOM	Volt-Ohm Meter

1.21 DEFINITIONS

Definitions and terms used within this Specification shall have the following meanings:

Analysis means a logical thought process which includes: clearly stated assumptions which can be justified, calculations with references for methods and equations stated, using data from simulation or, preferably, full-scale test, and clearly-stated conclusions which logically follow from the supporting calculations and data.

Brake, Air means a combination of devices operated by compressed air, arranged in a system, and controlled manually or pneumatically, by means of which the motion of a car or locomotive is retarded or arrested.

Brake Control System means the components including software that either automatically or under the control of the engineer cause changes in the retarding force applied to the train by the brake system.

Brake, Conventional Air means an air brake system designed in accordance with the current Manual of Standards and Recommended Practices of the Association of American Railroads.

Brake, Electric is a general term covering both rheostatic and regenerative braking.

Brake, Regenerative means braking in which kinetic energy is converted to electrical energy in the traction motors, transferred by the control system through the DC link, and returned to the contact line.

Brake, Rheostatic means braking in which kinetic energy is converted to electrical energy in the traction motors, transferred by the control system through the DC link, and dissipated in resistors on the locomotive.

Cab means that portion of the superstructure of the locomotive designed to be occupied by the crew operating the train.

Cab, controlling means the cab from which the engineer exercises control over the train.

Car, Passenger means a rail vehicle designed and used to transport passengers.

Contractor means the successful offeror for this contract after award.

Crew Member means an SEPTA employee involved in the on-board operation of the train.

Emergency Application means a brake application resulting in the maximum retarding force available from the train brake system.

Day means calendar day.

Front End means the end of a vehicle or rolling stock unit facing the direction of travel.

Full-Service Application means a brake application which results from one or more brake pipe reductions sufficient in amount to cause a full service reduction.

Program means the process of procurement, design, construction, testing, acceptance and warranty support of Training Simulators for SEPTA.

Service-Proven refers to components or systems, and means that these items offer a demonstrated history of satisfactory performance with a high level of availability under duty cycle and environmental conditions.

Software Plan means a controlled, orderly process to develop, produce, test, and verify safe and reliable computer programs for the Training Simulator.

Supplier means a supplier of material to the Contractor.

END OF SECTION

2 DESIGN CRITERIA AND REQUIREMENTS

2.1 GENERAL

2.1.1 Human Engineering

The Training Simulator design shall be based on human factors engineering. Special emphasis shall be placed on all vehicle interactions. All switches and controls shall be mimic actual control and response behaviors. The design and placement of the simulator controls, indicators, and relative seat position shall be as close to actual cab locations as possible and shall be arranged to have the most ergonomic layout possible.

2.1.2 Design Life

The Training Simulators and Workstations shall be designed and manufactured to perform satisfactorily for a minimum of 15 years.

2.1.3 Maintenance Periods

Safety, reliability and ease of maintenance shall be the primary design consideration as described in Sections 2.11 and 2.12. No component shall require periodic maintenance or calibration any more frequently than 1 year.

2.1.4 Equipment Access

All hardware which requires inspection or maintenance must be readily accessible and replaceable. In general, frequency of required service shall determine the degree of equipment accessibility. The Contractor shall prepare for Engineer approval during the Concept Design Phase sessions a tabulation of all controls or resets which may be required to access in order to restore the Training Simulator to a fully functional condition.

2.1.5 Interchangeability

Master controllers, throttles, and brake valves used on the actual equipment shall be integrated in the design of each Training Simulator. Model numbers for identical components shall be identical. Replaceable components of any such apparatus shall be fully interchangeable, without adjustments to

any part or system being necessary. Microprocessor hardware units which are physically identical except for the software shall have identical part numbers. An Engineer approved subpart number may be used to identify differences by software. Specific approval shall be obtained from the Engineer during Design Review or each part whose replacement may require an adjustment, and such approval may be granted only where it can be shown to be absolutely necessary.

2.1.6 Training Simulator and Workstation Designations

Each type of Training Simulator and Workstation shall be assigned a unique designator and be numbered consecutively within each type. A permanent affixed metal plate shall be installed on each Training Simulator and Workstation. This plate shall indicate the manufacturer, the manufacturer's address and contact information, the unique designator, the manufacturer's serial number, and the date of manufacture.

Each peripheral device shall also be assigned a unique designator for the purpose of identifying during operation and troubleshooting.

2.2 DESIGN CONSIDERATIONS

2.2.1 Training Simulator Design Requirements

The Training Simulator shall provide a realistic environment and experience, including sound simulation and visual cues, to Operators on the operation of the equipment over all territory on which SEPTA operates.

The Training Simulator shall be designed to be compliant as a "*Type II Simulator*" as defined in 49 CFR Part 240.7. The Training Simulator shall be designed so that SEPTA will have the means and capability to maintain the graphical environment presented to the Trainee to accurately reflect the physical characteristics of the right of way at all times. The Training Simulator shall permit SEPTA to re-certify operators according to SETPA's rules and regulations. In accordance with this requirement, SEPTA shall have the ability to modify all modeled elements related to the physical characteristics of the right of way, as well as the functional and operational characteristics of all equipment and control systems simulated within this environment.

The primary functions of the Training Simulator are:

1. Provide information, familiarization and understanding regarding the operation of SEPTA City Transit Division equipment.
2. Afford operators the ability to practice skills to attain a level of proficiency required for qualification.

3. Develop and apply skills to improve situational awareness.

The Training Simulator shall be a fully integrated interactive operator training program using Computer Generated Imagery (CGI) to model the operating cab controls and track arrangements including reverse movements.

The Training Simulator shall be capable of evaluating Trainee performance through assessment. An assessment criterion is to be developed in conjunction with the needs and requirements of the SEPTA's Transportation and Training Departments.

The Training Simulators shall be based upon a proven design and incorporate the latest simulator technology. The Training Simulators shall employ proven techniques that have adequately demonstrated compliance with the requirements of the railroad industry.

The Training Simulator and the Instructor's Workstations shall incorporate a modular design to allow for future modifications and additions without requiring changes or modifications to the computer hardware, software and interface architecture.

All computers shall be built by an ISO 9001 certified manufacturer. PC processors shall be Intel Xeon E5-1620 v4 or approved equal. RAM shall be 2400 MHz, DDR4, and of no less than 16GB in capacity or approved equal. Hard drives shall be Solid State SATA class 20 and of no less than 512GB in capacity or approved equal.

High speed DVD-RW with CD-RW capability drive (or drives) shall be included in addition to any other high capacity removable drive formats used by the Contractor for information exchange. Each computer shall have a complete audio system, be equipped for high speed internet connections. Additional Ethernet connections shall be also included for networking computers and printers within the Simulator Training Facility. Each unit shall be USB 3.0 capable. Hard-wired networking hubs and software shall be provided so that each computer station will have full use of the equipment.

2.2.2 Training Simulator Objectives

The Training Simulator shall present training opportunities with respect to basic skill development, acceleration, braking, station stops, and situational awareness decision-making skills and judgment. The Training Simulator will emulate all cab functions that are necessary to train and certify operating and mechanical personnel.

The Training Simulator shall be used as a tutorial for operators and Mechanical Department personnel on how to set up the train for departure and on how to troubleshoot typical failure modes found on the equipment. Diagnostics screens/information shall be presented as on actual equipment.

The Training Simulator shall evaluate basic train operation and handling as well as rules and response to unusual events. Each simulator will be capable of challenging crews with multiple concurrent tasks and encounters with atypical situations including different weather conditions.

2.2.3 Training Objectives

Simulator training will provide experience with realistic operation prior to the actual training on service lines. This training will be supported by familiarity and learning experiences gained by interaction with the Training Simulator. The basic training objectives include:

1. Training of new hires in train operation, train preparation, train handling, rules and regulation compliance, adherence to fault and failure procedures.
2. Operation of the train in normal and disrupted service scenarios providing experience and performance measurement with regard to signals, operating rules, operation over all tracks in either direction, and efficient on-time performance.
3. Accurate stopping at platforms.
4. Familiarization with the physical characteristics of the operating territory.
5. Requalification of operators as provided for by SEPTA's City Transit Division rules and regulations.

2.2.4 Critical Response Training Objectives

Each simulator will be capable of challenging crews will multiple concurrent tasks and encounters with atypical situations. The primary objective is to raise the Trainee's situational awareness and assist developing the proper actions under these circumstances. These situations include, but are not limited to:

1. Operation of the train in different weather conditions including sun, fog, rain, and snow.
2. Communication between Trainee and the instructor.
3. Schedule disruptions, tracks out of service, and emergency evacuation.
4. Automobiles on track and crossings (where applicable).
5. Trespassers or other obstructions on the right-of-way.
6. Crossing to unusual tracks and taking abnormal track routes.
7. Movement through interlockings.
8. Single tracking operations.
9. Signal problems including wayside/cab signal nonconformance and route/aspect nonconformance.
10. Speed restrictions and slow orders.
11. Work orders, work zones, and work equipment on adjoining tracks.

12. Proper use of Flags and Fusee.
13. Improperly lined switches.
14. Equipment failures.
15. Track anomalies.
16. Unsafe conditions.
17. Use of Stop & Proceed button.
18. Passengers falling into track area.
19. N-5 specific objectives:
    (a) Z-moves
20. Single and Double End LRV specific objectives:
    (a) Automobiles on track and crossings.
    (b) Passengers exiting vehicle and crossing in front of vehicle.
    (c) Close clearance conditions and passing another LRV.
    (d) Use of Push to Start button.

2.2.5 Operational Characteristics

Impact on train handling and performance as a function of passenger loading, size of consist, grades, curves, and environmental conditions shall be included in the design of the simulator software.

The instructor Workstation shall be capable of selecting pre-programmed training sessions and operating conditions from a database. The instructor shall also be able to introduce new and override running scenarios at any of the Trainee Workstations in order to confront the Trainee with unplanned situations as they might occur in the operating environment.

Common faults, malfunctions, and failure modes such as inability to charge brake pipe, loss of propulsion power, cab signal failures, or non-conformance shall be simulated. Simulation of rescue operations shall include coupling. Once coupled, the simulation shall provide the capability for the scenario to continue with operation and movement of the rescued train. Changes in train characteristics resulting from coupling (i.e. mass of the coupled train) are not required.

The software shall be designed so additional types of equipment not currently operated by SEPTA can be modeled and simulated to determine performance with varying consists and passenger loading on SEPTA-operated routes.

2.2.6 Environmental Factors

The Training Simulator shall not be a dynamic system that mimics equipment motion.

The audio environment shall simulate cab and background noises including, but not limited to: radio, cab signaling systems, passenger emergency intercoms, PA/IC communications, communication signal buzzers, station announcements, cab heater blowers, defect detectors, wheel/rail interface, coupling and uncoupling, brake applications, environmental effects (wind, rain, etc.). The instructor Workstation shall have the ability to communicate with the Trainees though any of the above mentioned communication systems. The quality of the audio experience shall mimic real world conditions such as Doppler effects, echoing, etc.

2.2.7 Route Characteristics

The Training Simulator shall use CGI or better based graphics to replicate the physical characteristics of the operating territory. CGI or better graphics shall have right-of-way details sufficient to allow Trainees to recognize important landmarks, stations, trackwork, switches, signals, and interlockings needed for proper train operation. The Training Simulator shall allow for the use of all tracks and signals displayed. Training Simulators shall only operate on the lines associated with their respective equipment. The graphics database shall include the physical characteristics of the following routes:

Equipment	Line	Between	Unique Route Length	Total Route Length
M-4	Market-Frankford Line	69th St. Transportation Ctr. to Frankford Transportation Ctr.	13 mi.	13 mi.
B-4	Broad Street Line	Fern Rock to AT&T Station	5.0 mi.	9.9 mi.
B-4	Broad Ridge Spur	Fern Rock to 8th-Market	2.0 mi.	6.9 mi.
N-5	Norristown High Speed Line	69th St. Transportation Ctr. to Norristown Transportation Ctr.	13.4 mi.	13.4 mi
Single End LRV	Trolley Route 10	13th-Market to 63rd-Malvern	5.6 mi	11.2 mi
Single End LRV	Trolley Route 11	13th-Market to Darby Transportation Ctr.	4.2 mi.	8.2 mi
Single End LRV	Trolley Route 13	13th-Market to Yeadon & Darby Tranportation Ctr.	4.3 mi.	7.7 mi
Single End LRV	Trolley Route 34	13th-Market to 61st-Baltimore	2.4 mi.	4.9 mi.

Single End LRV	Trolley Route 36	13th-Market to 80th-Eastwick	2.8 mi.	5.7 mi.
Double End LRV	Trolley Route 101	69th St. Transportation Ctr. to Media	9.6 mi.	11.7 mi.
Double End LRV	Trolley Route 102	69th St. Transportation Ctr. to Sharon Hill	7.1 mi.	9.2 mi.

The detail of the right-of-way physical characteristics shall be provided by SEPTA. Yards, loops, and sidings shall be included in their associated lines. Specific start and end points for each selectable line shall be determined in design phase and approved by SEPTA.

2.2.8 Training Simulator Workstation

Each Training Simulator Workstation shall consist of the following:

1. A simulated control desk, control stand, or EMU control equipment. The desk consoles realistic enhanced visual displays can be used in place of the speed indicator, the load current meter, air gauges, cab signal displays, and indicator panel lights. Substituting a physical control for a touch screen control shall require approval by the Engineer unless already allowed by TS 2.3. Remote panels containing essential controls shall also be modeled and integrated into the design of each Training Simulator.
2. All controls, devices, and components appropriate to the type of equipment being simulated shall be authentic to those found on the actual equipment or as approved by the engineer.
3. All labels both printed on and near controls and indicators, authentic to those found on the actual equipment or as approved by the engineer.
4. A high resolution, realistic, and flexible computer generated forward visual. All visuals shall replicate the field of view available to the operator in proper perspective for the particular equipment being modeled for simulation.
5. A sound system which produces internal and external equipment sounds as encountered during normal and abnormal operation.
6. A camera which permits the instructor to monitor and record the Trainees actions.
7. Software which includes realistic train modeling, fault simulation, and performance measurement.

2.2.9 Training Instructor’s Workstations

Two (2) Instructor Workstations shall be configured for instructor use to oversee, configure and control the training process. Each Instructor’s Workstation shall be capable of simultaneous monitoring and control of no less than four (4) Training Simulators, independent of the type of simulator, without any

degradation of functionality. This simultaneous operation may include operation on the same segment of track or in different track segments.

The Instructor's Workstations shall be designed to control and monitor:

1. Up to four (4) Training Simulators, independent of type, simultaneously.
2. Monitor Trainee performance.
3. Facilitate voice and message communication with the Training Simulators on an individual basis or simultaneously.
4. Manage records and generate evaluation and performance reports.

The Instructor's Workstations shall enable the instructor to have full control of the simulation as well as closely monitor the Trainee's actions while in the simulator. The Instructor's Workstations shall have operation modes which enable the instructor to set an exercise in advance, monitor and record the Trainees performance and the associated video surveillance of the Trainee during the exercise and store the results of the exercise for later review. The instructor shall also be able to store and review the Trainee's performance and snapshots on the simulator. It shall be possible to save and store a minimum of 2,500 training hours.

From the Instructor's Workstation, the instructor shall be able to select the route used for an on-going exercise, change signals, as well as influence exercises by setting weather conditions, time of day and fault conditions. This shall be affected while on-line, i.e. during an on-going simulation as well as being preprogrammed into a scenario. The Instructor's Workstations shall be fully graphical and user-friendly, only basic computer knowledge shall be required to operate the instructor station.

The instructor shall be able to change the train's configuration (that is, the total number of cars) for any particular exercise through the instructor station. The following train configurations shall be available:

- M-4
    - 2 cars (1 married pair)
    - 4 cars (2 married pairs)
    - 6 cars (3 married pairs)
    - 8 cars (4 married pairs)
    - 12 cars (6 married pairs, rescue configuration)
- B-4
    - 1 car
    - 2 cars
    - 3 cars
    - 4 cars
    - 5 cars
    - 10 cars (rescue configuration)

- N-5
  - 1 car
  - 2 cars
  - 4 cars (rescue configuration)

- Single End LRV
  - 1 car
  - 2 cars
- Double End LRV
  - 1 car
  - 2 cars

The instructor shall be able to change the train's schedule and required stops.

Each Instructor’s Workstation shall be comprised of new, latest available technology, commercially available computer hardware and peripheral accessories. The following devices shall be included in each instructor's desk:

1. A computer Workstation (computer, keyboard, mouse, monitor, etc.).
2. Additional monitors for CCTV, Trainee field-of-view and overhead view.
3. A communications control console.
4. Controls for simulated interactive elements.
5. One color monitor for displaying the graphically based instructor software (MMI) for creating and supervising exercises, training menu, etc.
6. Appropriate furnishings to accommodate all Workstation hardware and documentation.
7. One high quality office chair.
8. Laser Printer (one networked printer shared between Instructor’s Workstations).

The Instructor’s Workstations shall be operated by means of a user-friendly, MS Windows-based graphical user interface. All functions within the user interface shall be intuitive and facilitated through the use of menus, point and click mouse controls and simple keyboard commands.

The Instructor’s Workstations shall be used to power up the Training Simulators, perform system shutdowns, troubleshoot, manage Trainee information, and change the Training Simulators performance level parameters. The Instructor’s Workstations shall be used to set up training simulations, monitor execution, control Trainee operations, and collect and record Trainee performance data.

The Instructor’s Workstations shall include an off-line performance analysis capability which allows both Trainees and instructors to review details of simulation performance in a graphical and user-friendly manner. The Instructor’s Workstations shall be capable of operating as a 'Preparation Workstation'. The

instructor station shall be configured for off-line scenario preparation, scoring templates creation and track database validation. The mode of operation shall be determined by password login.

A Windows Tablet or Laptop shall be provided to give the instructor the ability to travel to the simulator and continue instructor tasks at the simulator. The instructor shall be able to extend their control by connecting the remote tablet/laptop to a desired Instructor Station computer view using VNC remote control software. This design shall provide all instructor controls at a remote location near any of the simulators.

Using the Instructor's Workstation, instructors shall be able to simulate basic train functions, including, but not limited to, the following:

- Train preparation.
- Operating under both normal and degraded conditions.
- Use of cab equipment.
- Track and signal system anomalies.

The model will also include the ability to interject malfunctions into the train and its subsystems. The malfunctions should focus on those which require an operational response from the operator or those which occur with some frequency and for which overrides or bypasses exist in the simulated cabs. The M-4, B-4, and N-5 train models shall be provided with a number of faults not to exceed 25 per train model. The Single and Double End LRV train models shall be provided with a number of faults not to exceed 25 shared commonly between both models. The final selection of faults will be made in agreement with SEPTA. Simulated faults will include mechanical, pneumatic, and electrical faults.

2.2.10 Network Integration

The Contractor shall be responsible for all work needed to create the computer graphics and programming associated the Training Simulator.

The software shall be designed with a user interface to build SEPTA schedules for the simulated train**.** Each schedule shall be saved and made available for selection when creating scenarios**.**

The Base Work Scope requires the Training Simulator to be a stand-alone system and does not require the Training Simulator to be integrated in to SEPTA's existing information technology infrastructure and/or network.

2.3 CAB CONTROLS

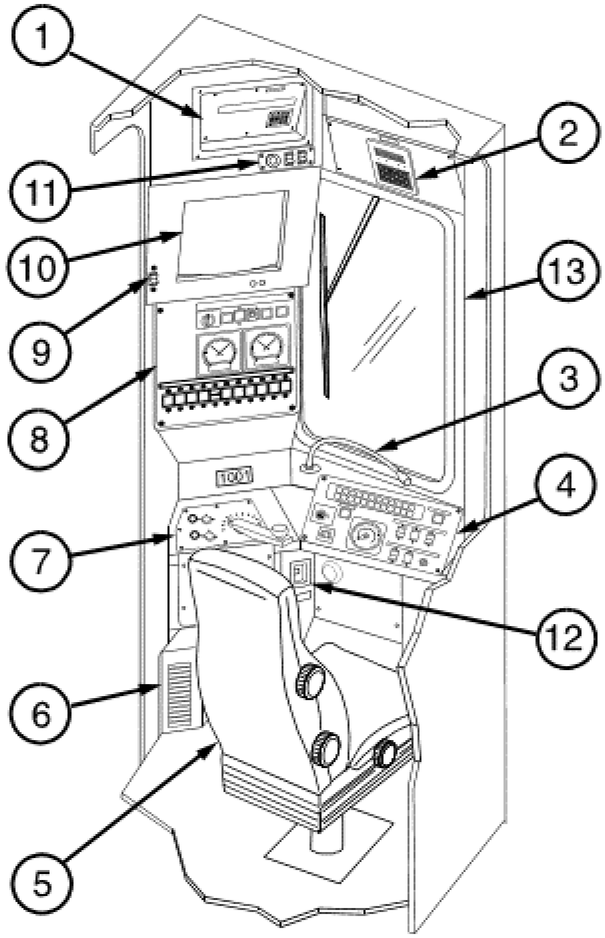
2.3.1 General

All materials for the construction of each of the Training Simulators are the responsibility of the Contractor. If a component cannot be procured by the Contractor, SEPTA, at its discretion, may be able to provide the obsolete component for the purpose of constructing the Training Simulator. However, under these circumstances, it is the sole responsibility of the Contractor to modify these SEPTA supplied materials in order to make them suitable for the Training Simulator.

In addition to the controls listed within TS 2.3, cut-outs and circuit breaker controls determined to be needed as part of an included fault procedure shall be included. These controls shall be present on a touch screen near the operator but removed from the operator's console. The available fault based controls shall be determined during design phase and approved by SEPTA.

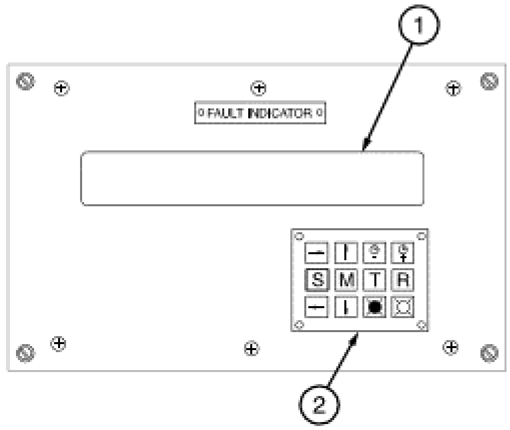
2.3.2 M-4

The following diagrams are provided for reference:



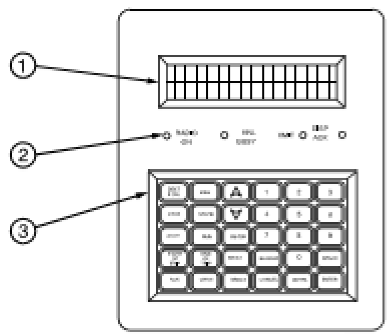
1 - FIS Panel
2 - Radio Control Display Unit (CDU)
3 - Microphone
4 - Main Cab Console
5 - Operator's Seat
6 - Cab Heater
7 - Master Controller
8 - Left Cab Console
9 - Left Door Enable Switch
10 - Door Operation Surveillance System Monitor
11 - Upper-Left Cab Panel
12 - AIR SEAT CUT-OUT Valve
13 - Right Door Enable Switch

Cab Area General Arrangement



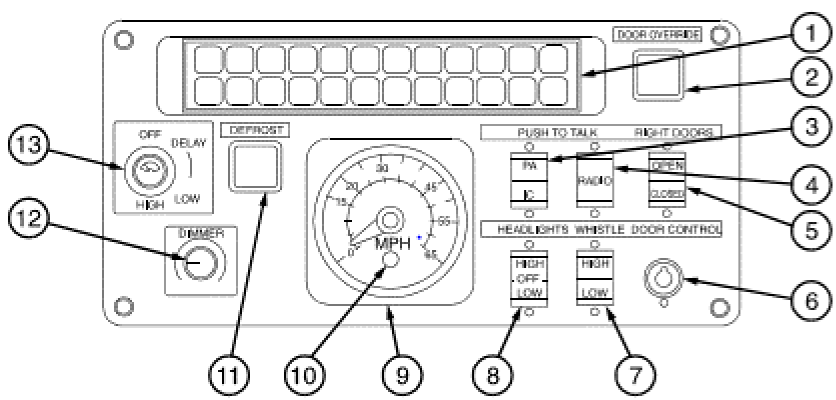
1 - Fault Indication System (FIS) Display
2 - FIS Keypad

Fault Indication System (FIS)



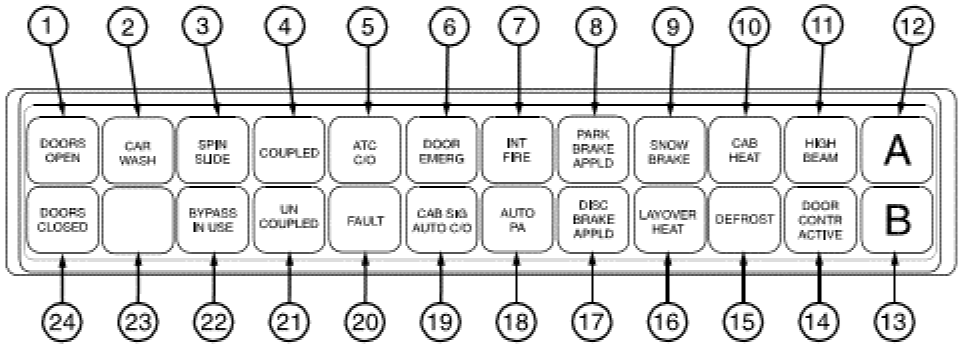
1 - Display
2 - Indicator Lights
3 - Keypad

Radio Control Display Unit (CDU)



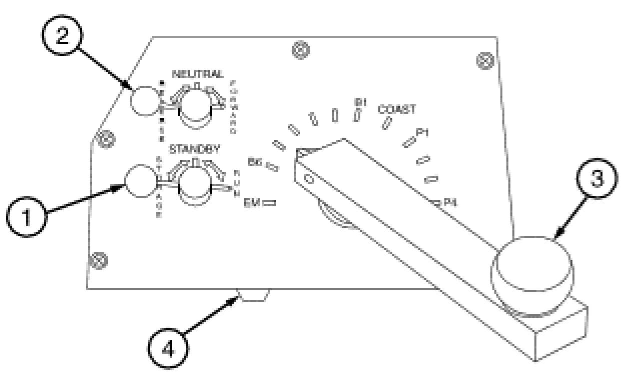
1 - Annunciator Panel
2 - DOOR OVERRIDE Switch
3 - PA/IC (Public Address/Intercom) Switch
4 - RADIO Switch
5 - RIGHT DOORS Switch
6 - DOOR CONTROL Key Switch
7 - WHISTLE Switch
8 - HEADLIGHTS Switch
9 - Speedometer/Cab Signal Display Unit
10 - OVERSPEED Indicator
11 - DEFROST Switch
12 - DIMMER Switch (Cab Display)
13 - Windshield WIPER Switch

Main Cab Console



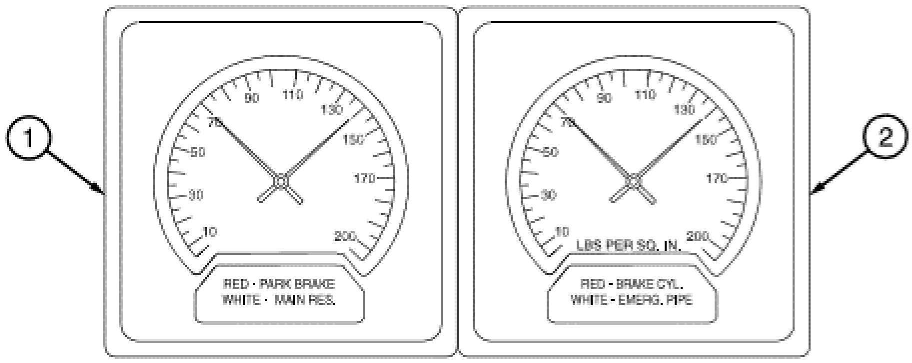
1 - DOORS OPEN (Red)
2 - CAR WASH (Amber)
3 - SPIN SLIDE (Amber)
4 - COUPLED (Green)
5 - ATC C/O (Amber)
6 - DOOR EMERG (Red)
7 - INT FIRE (Red)
8 - PARK BRAKE APPLD (Amber)
9 - SNOW BRAKE (Amber)
10 - CAB HEAT (Amber)
11 - HIGH BEAM (Amber)
12 - A (Route) (Amber)
13 - B (Route) (Amber)
14 - DOOR CONTR ACTIVE (Amber)
15 - DEFROST (Amber)
16 - LAYOVER HEAT (Amber)
17 - DISC BRAKE APPLD (Amber)
18 - AUTO PA (Amber)
19 - CAB SIGNAL AUTO C/O (Amber)
20 - FAULT (Red)
21 - UNCOUPLED (Amber)
22 - BYPASS IN USE (Amber)
23 - Spare (Amber)
24 - DOORS CLOSED (Green)

Annunciator Panel



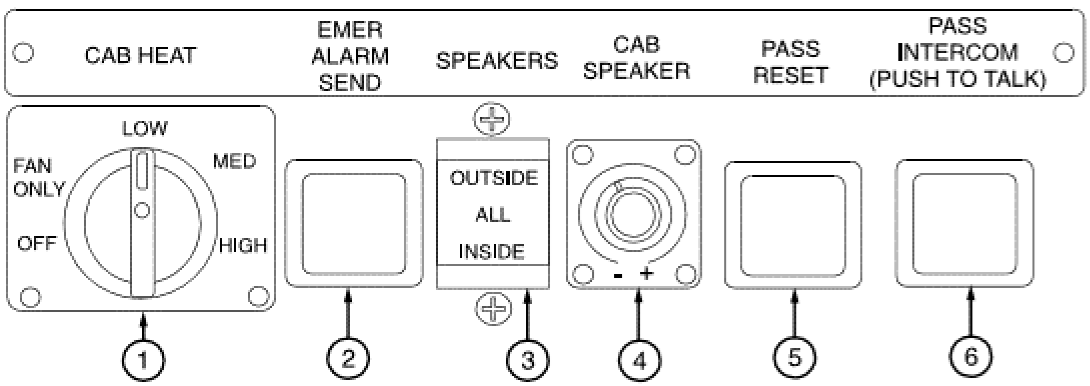
1 - Mode Switch
2 - Reverser Switch
3 - Controller Handle
4 - Control Key Switch

Master Controller



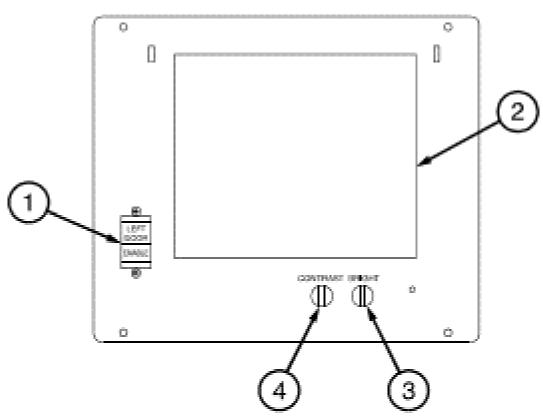
1 - Parking Brake and Main Reservoir Gauge
2 - Brake Cylinder and Emergency Pipe Gauge

Left Cab Console Dual Pressure Gauges



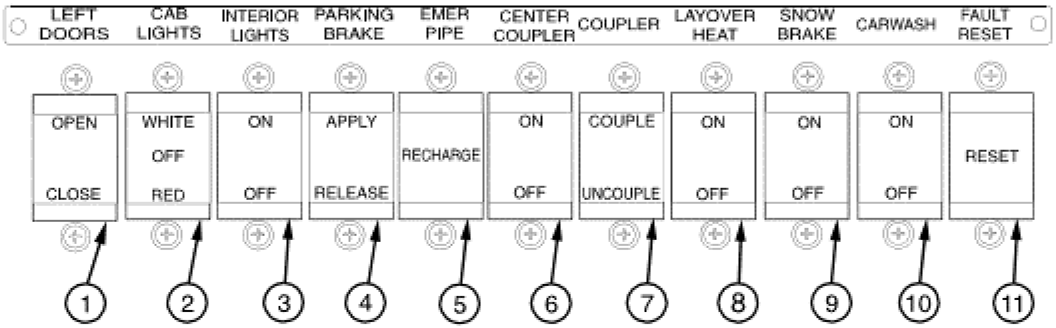
1 - CAB HEAT Switch
2 - EMER ALARM SEND Switch
3 - SPEAKERS Switch
4 - CAB SPEAKER Volume Control
5 - PASS RESET Switch
6 - PASS INTERCOM Switch

Left Cab Console Upper Panel Switches



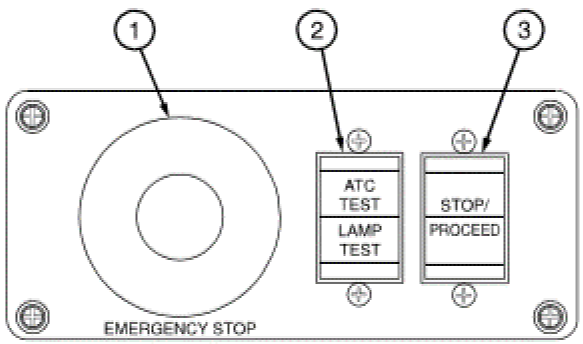
1 - LEFT DOOR ENABLE Switch
2 - Door Operation Surveillance System (DOSS) Monitor
3 - BRIGHT Control
4 - CONTRAST Control

Door Operation Surveillance System Monitor



1 - LEFT DOORS Switch
2 - CAB LIGHTS Switch
3 - INTERIOR LIGHTS Switch
4 - PARKING BRAKE Switch
5 - EMER PIPE Recharge Switch
6 - CENTER COUPLER Switch
7 - COUPLER Switch
8 - LAYOVER HEAT Switch
9 - SNOW BRAKE Switch
10 - CARWASH Switch
11 - FAULT RESET Switch

Left Cab Console Lower Panel Switches



1 - EMERGENCY STOP Pushbutton Switch
2 - ATC TEST-LAMP TEST Switch
3 - STOP/PROCEED Switch

Upper-Left Cab Panel

Cab controls and indicators to be included in the M-4 Training Simulator:

Fault Indication System (FIS)

Function	Switch Positions/Type	Representation
Fault Indication Display	Digital display	Active display
FIS Keypad	Keypad	Active control

Radio Control Display Unit

Function	Switch Positions/Type	Representation
Display	Digital display	Active screen
Indicator Lights	LED indicators lights	Active indicator (Green)
Keypad	Keypad	Active control

Main Cab Console

Annunciator Panel Indicators

Indicator	Representation
Door Open	Active indicator light (Red)
Car Wash	Active indicator light (Amber)
Spin Slide	Active indicator light (Amber)
Coupled	Active indicator light (Green)
ATC C/O	Active indicator light (Amber)
Door Emerg	Active indicator light (Red)
Int Fire	Inactive indicator light (Red)
Park Brake Appld	Active indicator light (Amber)
Snow Brake	Active indicator light (Amber)
Cab Heat	Inactive indicator light (Amber)
High Beam	Active indicator light (Amber)
A (Route)	Active indicator light (Amber)
B (Route)	Active indicator light (Amber)
Door Contr Active	Active indicator light (Amber)
Defrost	Inactive indicator light (Amber)
Layover Heat	Inactive indicator light (Amber)
Disc Brake Appld	Active indicator light (Amber)
Auto PA	Active indicator light (Amber)
Cab Signal Auto C/O	Active indicator light (Amber)
Fault Indicator	Active indicator light (Red)
Uncoupled	Active indicator light (Amber)
Bypass In Use	Active indicator light (Amber)
Spare	Inactive indicator light (Amber)
Doors Closed	Active indicator light (Green)

Function	Switch Positions/Type	Representation
Door Override Switch	Push button	Inactive control (Red)
PA/IC Switch	Three (3) position momentary rocker switch PA/No Input/IC	Inactive control (White)
Radio Switch	Two(2) position momentary rocker switch Enable/No Input	Active control (White)
Right Doors Switch	Three (3) position momentary rocker switch Open/No Input/Closed	Active control (White)
Door Control Key Switch	Rotary key switch	Active control
Whistle Switch	Three (3) position momentary rocker switch High/No Input/Low	Active control (White)
Headlights Switch	Three (3) permanent position rocker switch High/Off/Low	Active control (White)
Speedometer/Cab Signal Display	Analog dial with cab signal authorized speed indicators in MPH (0-65) & KPH (0-105) and overspeed indicator.	Active indicator
Defrost Switch	Push button	Inactive control (Red)
Dimmer Control	Rotary knob	Inactive control (Black)
Windshield Wiper Switch	Rotary knob	Inactive control (Black)

Master Controller

Function	Switch Positions/Type	Representation
Mode Switch	Three (3) position rotary switch with handle Storage/Standby/Run	Active control
Reverser Switch	Three (3) position rotary switch with handle Reverse/Neutral/Forward	Active control
Controller Handle	Depress and rotate lever with Deadman feature Enable/No Input	Active control
Control Key Switch	Rotary key switch	Active control

Left Console Dual Pressure Gauges

Function	Switch Positions/Type	Representation
Parking Brake & Main Reservoir Gauge	Two (2) needle pressure gauge Red (parking brake), white (main reservoir)	Active indicator
Brake Cylinder & Emergency Pipe Gauge	Two (2) needle pressure gauge Red (brake cylinder), white (emergency pipe)	Active indicator

Left Cab Console Upper Panel Switches

Function	Switch Positions/Type	Representation
Cab Heat Switch	Five (5) position rotary selector switch Off/Fans Only/Low/Medium/High	Inactive control
Emergency Alarm Send Switch	Momentary push button	Inactive control (Black)
Speakers Switch	Three (3) permanent position rocker switch Outside/All/Inside	Inactive control (White)
Cab Speaker Volume Control	Rotary knob	Inactive control (Black)
Pass Reset Switch	Momentary push button. Activating switch with passenger emergency intercom active changes state between Flashing/Illuminated/Off	Active control and indicator (Red)
Pass Intercom Switch	Momentary push button	Inactive control (Black)

Left Cab Console Lower Panel Switch

Function	Switch Positions/Type	Representation
Left Doors Switch	Three (3) momentary position rocker switch Open/No Input/Closed	Active control (White)
Cab Lights Switch	Three (3) permanent position rocker switch White/Off/Red	Inactive control (White)
Interior Lights Switch	Two(2) permanent position rocker switch On/Off	Inactive control (White)
Parking Brake Switch	Three (3) momentary position rocker switch Apply/No Input/Release	Active control (White)
Emergency Pipe Switch	Two (2) momentary position rocker switch Recharge/No Input	Active control (White)
Center Coupler Switch	Two (2) permanent position rocker switch On/Off	Active control (White)
Coupler Switch	Two (2) momentary position rocker switch w/guard Couple/Uncouple	Active control (White)
Layover Heat Switch	Two (2) position rocker switch On/Off	Inactive control (White)
Snow Brake Switch	Two (2) permanent position rocker switch On/Off	Active control (White)

Carwash Switch	Two (2) momentary position rocker switch On/Off	Active control (White)
Fault Reset Switch	Two (2) momentary position rocker switch Reset/No Input	Active control (White)

Door Operation Surveillance System (DOSS)

Function	Switch Positions/Type	Representation
Left Door Enable	Two (2) momentary position rocker switch w/guard Enable/NO Input	Active control (White)
DOSS Monitor	Displays left side platform view when left side platform is entered. Displays right side platform view when right side platform is entered. View shows passenger movement and embarking/disembarking.	Active display
Bright Control	Rotary knob	Inactive control
Contrast Control	Rotary knob	Inactive control

Upper Left Cab Panel

Function	Switch Positions/Type	Representation
Emergency Stop Button	Two (2) permanent position pushbutton with mushroom head Activated/Not Activated	Active control (Red)
ATC Test-Lamp Test Switch	Three (3) momentary position rocker switch ATC Test/No Input/Lamp Test	Active control (White)
Stop/Proceed Switch	Two (2) momentary position rocker switch Activated/No Input	Active control (White)

Right Door Enable Switch Area (Located to the right of Operator’s seated position)

Function	Switch Positions/Type	Representation
Right Door Enable	Two (2) momentary position rocker switch w/guard. Located to the right and behind Operator’s seated position. Enable/No Input	Active control (White)
Right Side Platform Monitor	Located to the right of Operator’s seated position. Displays right side platform view with passenger movement, including embarking/disembarking.	Active display

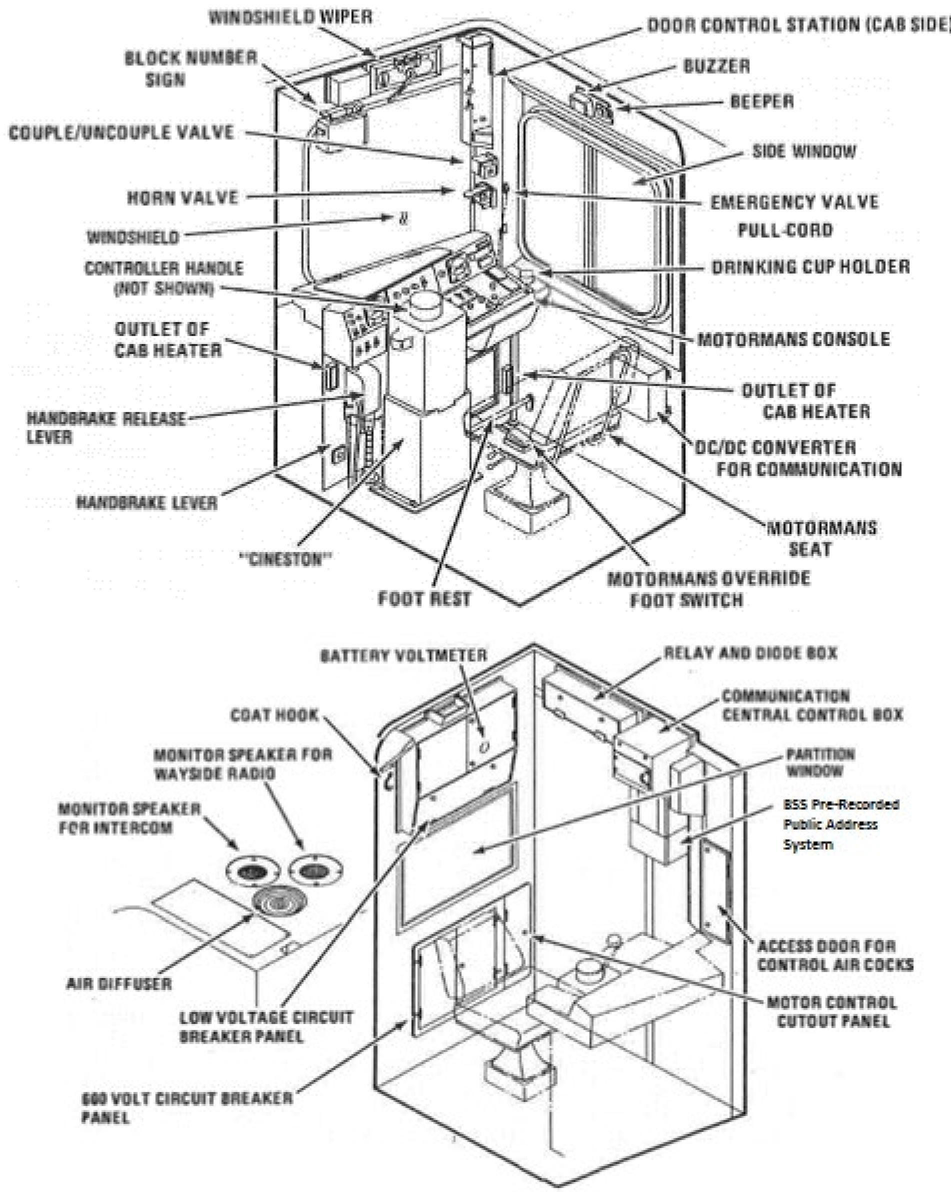
Not in reach while operating the simulator

Function	Switch Positions/Type	Representation
Friction Brake Cutout “F” End	Circuit breaker style switch On/Off	Active control
Friction Brake Cutout “R” End	Circuit breaker style switch On/Off	Active control
Traction Motor Cutout “F” End	Rotary breaker style switch Normal/Cutout	Active control
Traction Motor Cutout “R” End	Rotary breaker style switch Normal/Cutout	Active control
Regeneration Cutout	Rotary breaker style switch Normal/Cutout	Active control

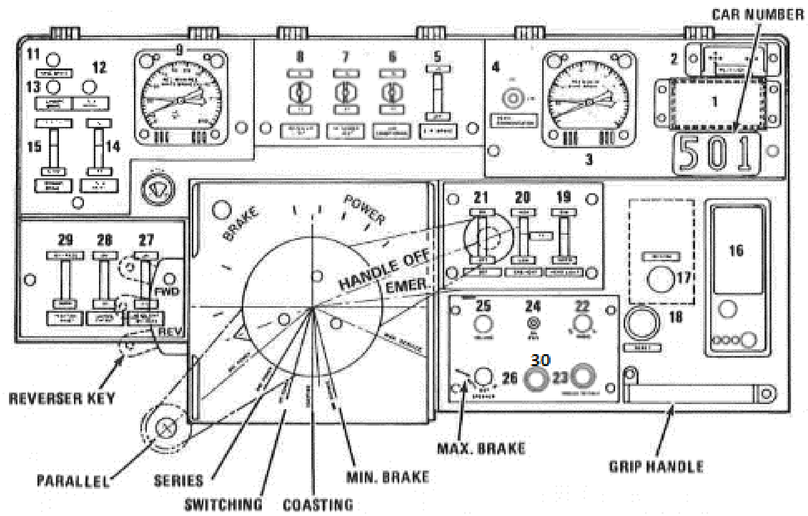
ATC Cutout	Rotary switch Normal/Cutout	Active control

2.3.3 B-IV

The following diagrams are provided for reference:

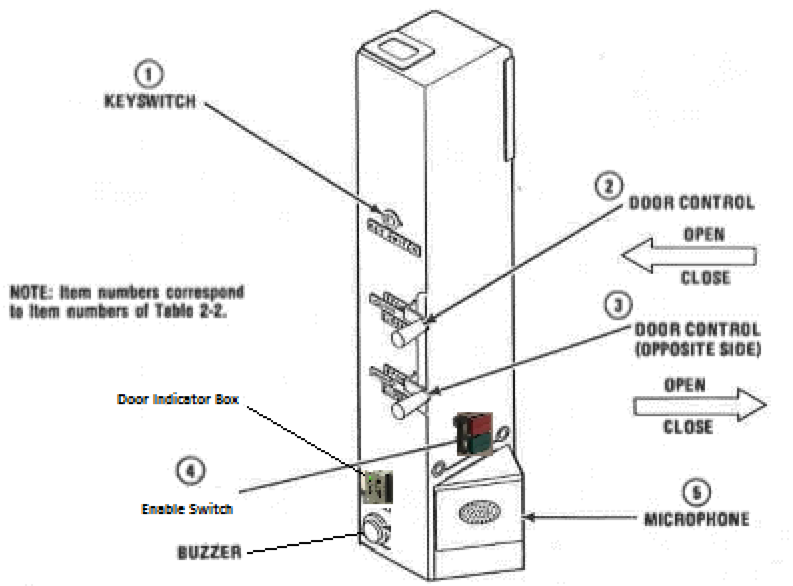


Cab Area General Arrangement

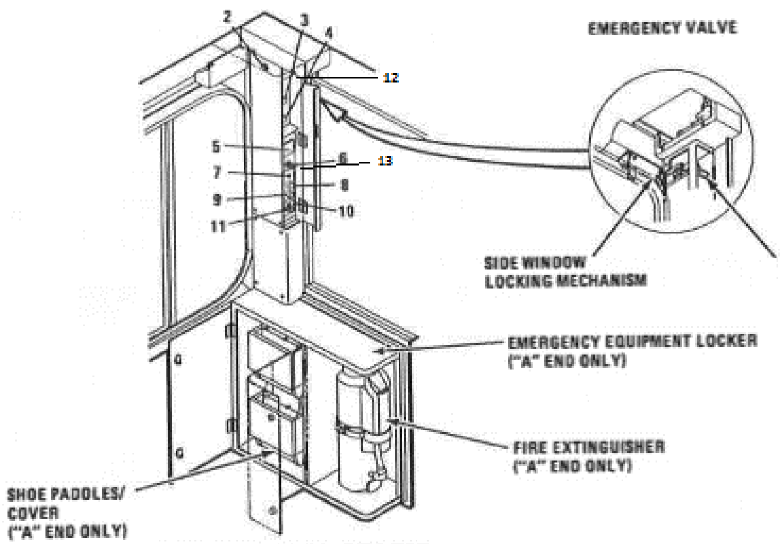


1- Speedometer
2- Pilot Light
3- Air Pressure Gauge
4- Heat/Communication
5- E-P Brake
6-Air Conditioning
7- Passenger Heat
8- Passenger Light
9- Air Pressure Gauge
10- Wiper
11-Handbrake Indicator
12- LSD Bypass Indicator
13- Dynamic Brake Indicator
14- LSD Bypass Switch
15- Dynamic Brake Switch
16- AVI & Routing Code Selector
17- Routing Code Key
18- Reset
19- Headlight
20- Cab Heat
21- Defroster
22- PA
23- Press to Talk
24- Power On
25- Volume
26- Speaker Selector
27- Headlight Bypass
28- Control Cutout
29- Traction Inhibit
30- PA/IC

Operator's Console



Door Control Station (Operator's Side)



1 - Emergency Brake	8-Volume
2- Key Switch	9- Speaker In/Out
3- Door Control (Right Side)	10- PA, Padio
4- Door Control (Left Side)	11-Push to Talk
5- Buzzer	12- Door Indicator Box
6-Microphone	13- Enable Switch
7-On Power	

Door Control Station (Opposite Operator's Side)

Pre-Recorded Public Address System

Cab controls and indicators to be included in the B-4 Training Simulator:

Cab Area

Function	Switch Positions/Type	Representation
Couple/Uncouple Valve	Couple key operated rotary switch Uncouple/Couple	Active control
Emergency Valve Pull Cord	Pull cord	Active control
Override Foot Switch	Foot pedal, prevents the side doors from opening and sounds buzzer while depressed.	Active control
Handbrake	Two (2) permanent position push button	Active control
Horn Valve	Lever, continuous sound while depressed.	Active control
BSS Pre-Recorded Public Address System	Digital display with push button selectors.	Active display with controls

Operator's Console

Function	Switch Positions/Type	Representation
Speedometer	Red digital numbers (in MPH)	Active display
Pilot Light	Indicator light	Active indicator (Green)
Air Pressure Gauge	Two (2) needle pressure gauge Red (straight air pipe), White (brake pipe)	Active indicator
Master Controller	Control handle, rotary lever with Deadman feature	Active control
Heat/Communication	Two (2) position rotary key switch On/Off	Inactive control
E-P Brake	Two (2) permanent position toggle switch On/Off	Active control
Air Conditioning	Two (2) momentary position toggle switch On/Off	Inactive control
Passenger Heat	Two (2) momentary position toggle switch On/Off	Inactive control
Passenger Light	Two (2) momentary position toggle switch On/Off	Inactive control
Air Pressure Gauge	Two (2) needle pressure gauge Red (main reservoir), White (brake cylinder)	Active indicator
Wiper	Rotary knob	Inactive control
Handbrake Indicator	Indicator light	Active indicator (Red)
LSD Bypass Indicator	Indicator light	Active indicator (Orange)
Dynamic Brake Indicator	Indicator light	Active indicator (Red)
LSD Bypass Switch	Two (2) permanent position toggle switch On/Off	Active control
Dynamic Brake Switch	Two (2) permanent position toggle switch Cutout/Normal	Active control
AVI	Push button switches "A" Route/"B" Route/Cancel/Unsched	Active control
Routing Code Selector	Three (3) push wheel switches 0-9/0-9/letters	Active display
Routing Code Key	Placard with routing codes	Sign
Headlight Switch	Two (2) permanent position toggle switch Dim/Normal	Active control
Cab Heat	Three (3) permanent position toggle switch High/Off/Low	Inactive control

Defroster	Two (2) permanent position toggle switch High/Off/Low	Inactive control
PA (Next Announcement)	Push button	Active control (Red)
Press to Talk	Push button	Active control (Green)
Power On	Indicator light	Inactive indicator (Red)
Volume	Rotary knob	Inactive control
Speaker In/EXT/Both	Three (3) position selector switch Internal/External/Both	Inactive control
PA/IC	Two (2) position rotary switch PA/IC	Inactive control
Headlight Bypass	Two (2) permanent position toggle switch On/Off	Active control
Control Cutout	Two (2) permanent position toggle switch On/Off	Active control
Traction Inhibit	Two (2) permanent position toggle switch Bypass/Normal	Active control

Door Control Station (Operator's Side)

Function	Switch Positions/Type	Representation
Key Switch	Standard key rotary switch On/Off	Inactive control
Door Control (Right Side)	Two (2) momentary position lever switch Open/Closed	Active control
Door Control (Left Side)	Two (2) momentary position lever switch Open/Closed	Active control
Buzzer	Push button	Active control (Black)
Microphone	Microphone	Active control
Door Indicator Box	Indicator lights On (Green)/Enable (Amber)/Left Door Open (Red)/ Right Door Open (Red)	Active indicator
Enable Switch	Two (2) push button switches Disengage (Red)/Engage (Green)	Active control
Right Side Platform Monitor	Located to the right of Operator's seated position. Displays right side platform view with passenger movement, including embarking/disembarking.	Active display

Door Control Station (Opposite Operator's Side)

Function	Switch Positions/Type	Representation
Emergency Brake	Pull handle	Active control (Red)
Door Control (Right Side)	Two (2) momentary position lever switch Open/Closed	Active control
Door Control (Left Side)	Two (2) momentary position lever switch Open/Closed	Active control
Buzzer	Push button	Active control (Black)
Microphone	Microphone	Active control
Enable Switch	Two (2) push button switches Disengage (Red)/Engage (Green)	Active control
On Power	Indicator light	Active indicator (Red)
Push to Talk	Push button	Active control

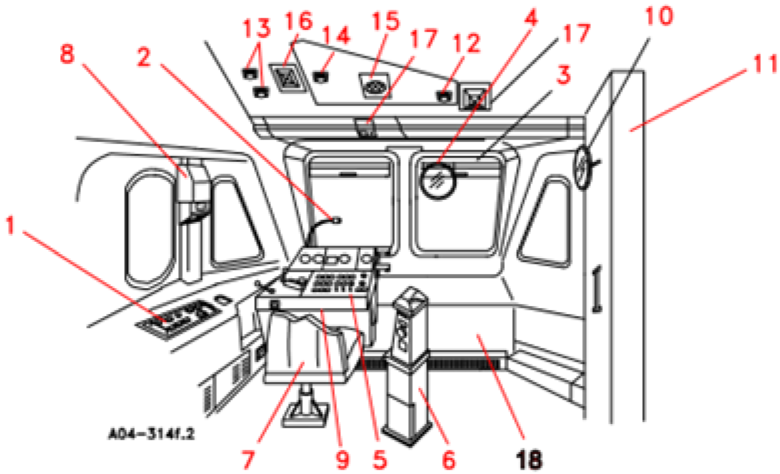
Left Side Platform Monitor	Located to the left of Operator's seated position. Displays right side platform view with passenger movement, including embarking/disembarking.	Active display

Not in reach while operating the simulator

Function	Switch Positions/Type	Representation
Friction Brake Cutout	Two (2) position switch sealed in cut-in position Cut In/ Cut Out	Active control
Motor Cutout 600V Switch Panel	Two (2) position selector switch In/Out	Active control

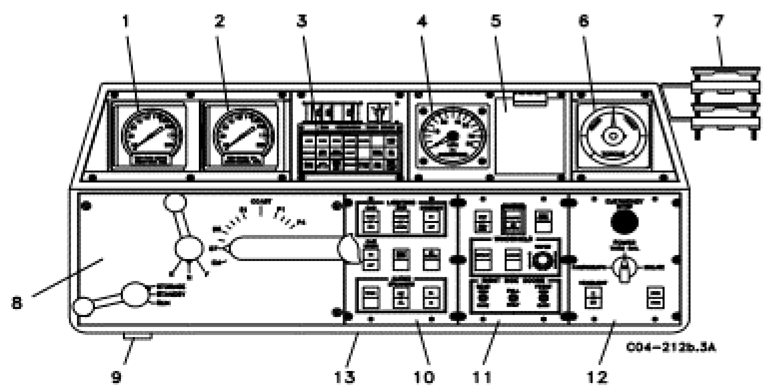
2.3.4 N-5

The following diagrams are provided for reference:



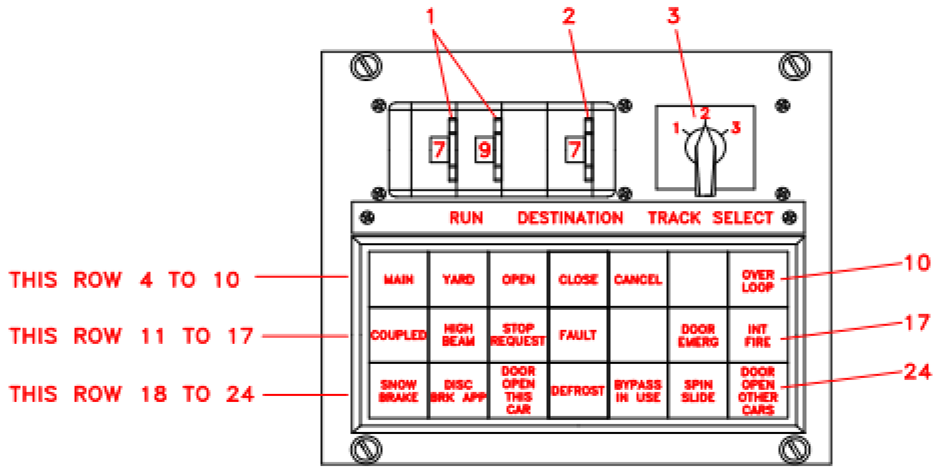
1. Operator Left Side Console (Fig. 1-23)
2. Microphone
3. Windshield Curtain
4. Interior Rear View Mirror
5. Operator Cab Console (Fig. 1-16)
6. Farebox
7. Operator Seat
8. Radio (Fig. 2-2)
9. Operator Emergency Alarm (under console)
10. Side Door and Vestibule Mirror
11. Crew Locker
12. Farebox Light
13. Cab Interior Lights (red)
14. Cab Interior Light (white)
15. Public Address/Intercom Speaker
16. Air Conditioning Vents
17. Destination Sign Control Switch and Peephole
18. Sandbox

Cab Area General Arrangement



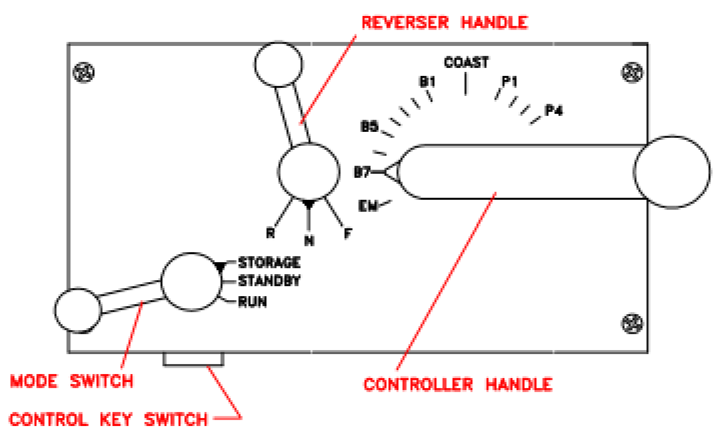
1. Parking Brake and Main Reservoir Air Gauges
2. Brake Cylinder and Emergency Pipe Air Gauges
3. Annunciator Panel (Fig. 1-17)
4. Speedometer/Cab Signal Display (Fig. 1-18)
5. Clipboard
6. Torque Meter
7. Transfer Cutters
8. Master Controller, Reverser and Mode Switch (Fig. 1-19)
9. Control Key Switch
10. Lighting/Communication Panel (Fig. 1-20)
11. Windshield/Door Panel (Fig. 1-21)
12. Emergency Stop/Power Changeover Panel (Fig. 1-22)
13. Operator Emergency Alarm Pushbutton (under console)

Operator Cab Console

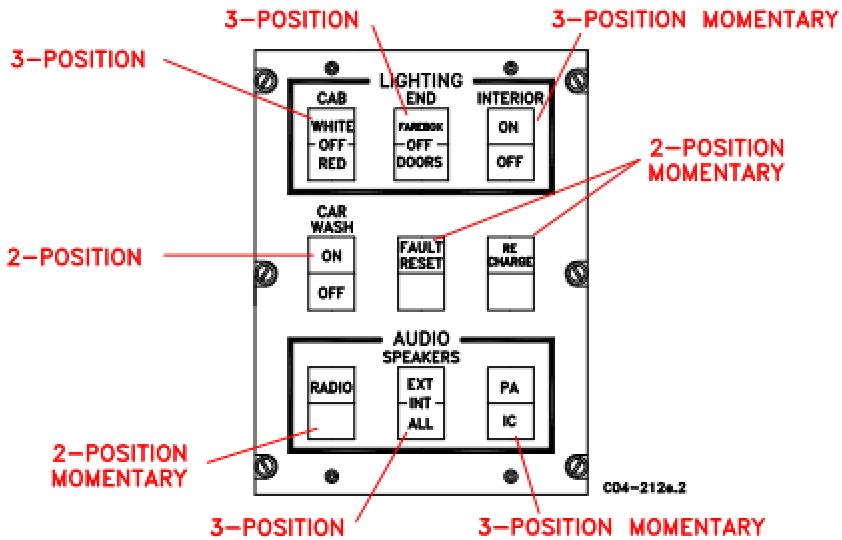


1. VETAG Run Number Thumbwheel Switch (00 to 79)
2. VETAG Destination Code Thumbwheel Switch (0 to 7)
3. VETAG Terminal Track Selection Switch (1-2-3)
4. Main Track Route Selection Pushbutton
5. Yard Track Route Selection Pushbutton
6. Yard Switch Open Command Pushbutton
7. Yard Switch Close Command Pushbutton
8. Route Selection Cancel Pushbutton
9. (Not Used)
10. Overloop Indicator (green)
11. Coupled Indicator (green)
12. Headlight High Beam Indicator (green)
13. Passenger Stop Request Indicator (green)
14. Fault Indicator (red)
15. (Not used)
16. Door Emergency Indicator (red)
17. Interior Fire Indicator (red)
18. Snow Brake Indicator (amber)
19. Disc Brakes Applied Indicator (amber)
20. Door Open This Car Indicator (amber)
21. Windshield Defroster in Use Indicator (amber)
22. Bypass In Use Indicator (amber)
23. Spin/Slide Indicator (amber)
24. Door Open Other Cars Indicator (amber)

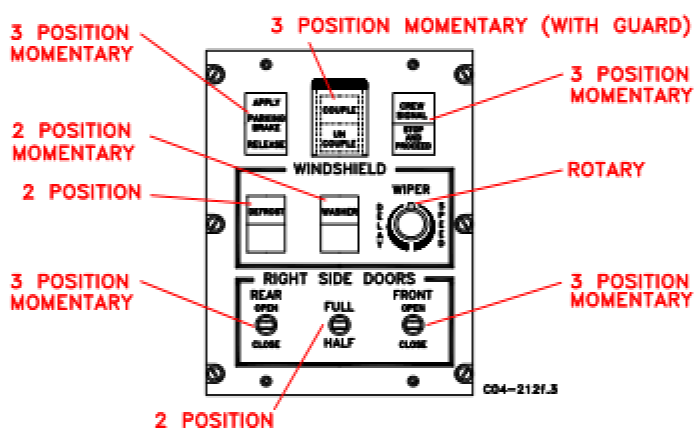
Annunciator Panel



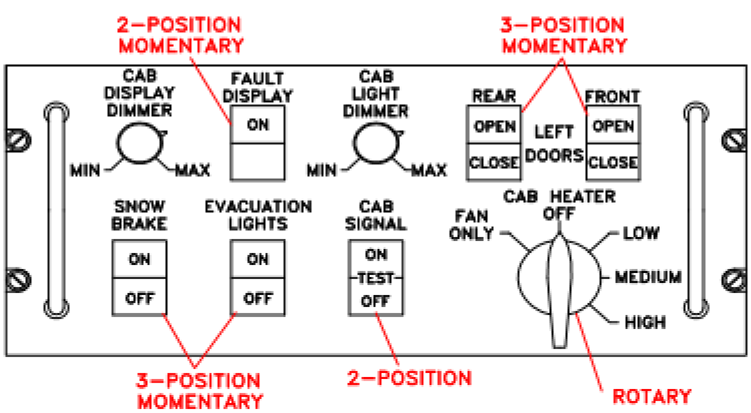
Master Controller



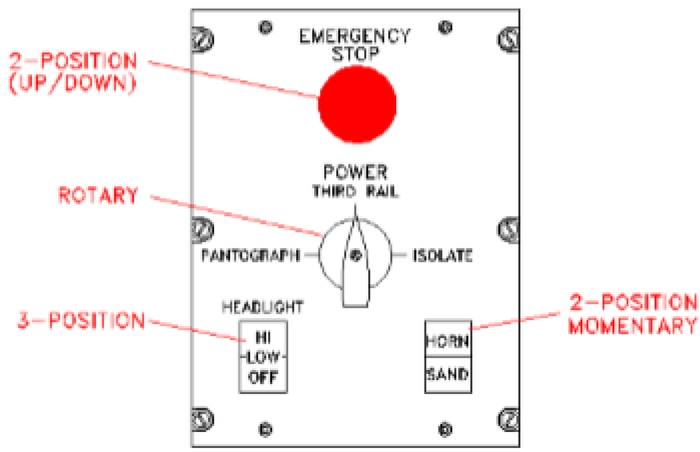
Lighting/Communication Panel



Windshield/Door Panel



Left Side Console



Emergency Stop/Changeover Panel

Cab controls and indicators to be included in the N-5 Training Simulator:

Cab Area

Function	Switch Positions/Type	Representation
Microphone	Gooseneck microphone	Active control
Radio	Radio with push to talk on hand set	Active control

Operator Cab Console

Function	Switch Positions/Type	Representation
Parking Brake & Main Reservoir Air Gauges	Two (2) needle pressure gauge Red (parking brake), White (main reservoir)	Active indicator
Brake Cylinder & Emergency Pipe Air Gauges	Two (2) needle pressure gauge Red (brake cylinder), White (emergency pipe)	Active indicator
Speedometer/Cab Signal Display	Analog dial with cab signal authorized speed indicators in MPH (0-80)	Active indicator
Torque Meter	Needle gauge Red left side (brake), Green right side (power)	Active indicator
Master Controller	Control handle, rotary lever with Deadman feature	Active control
Reverser	Three (3) position selector switch Reverse/Neutral/Forward	Active control
Mode Switch	Three (3) position selector switch	Active control
Control Key Switch	Key operated rotary switch	Active control

Annunciator Panel

Function	Switch Positions/Type	Representation
VETAG Run Number	Two (2) numbered thumb wheels 00 through 79.	Inactive display
VETAG Destination Code	Numbered thumb wheel 0 through 7. Display with values changeable by instructor.	Active display
VETAG Terminal Track Selection Switch	Three (3) position rotary switch 1/2/3	Active control
Main Track Route Selection Switch	Pushbutton	Active control (white)
Yard Track Route Selection Switch	Pushbutton	Active control (white)

Yard Switch Open Command	Pushbutton	Active control (white)
Route Selection Cancel	Pushbutton	Active control (white)
Overloop Indicator	Indicator light	Active indicator (Green)
Coupled Indicator	Indicator light	Active indicator (Green)
Headlight High Beam Indicator	Indicator light	Active indicator (Green)
Passenger Stop Request Indicator	Indicator light	Active indicator (Green)
Fault Indicator	Indicator light	Active indicator (Red)
Door Emergency Indicator	Indicator light	Active indicator (Red)
Interior Fire Indicator	Indicator light	Inactive indicator (Red)
Snow Brake Indicator	Indicator light	Active indicator (Amber)
Disc Brake Applied Indicator	Indicator light	Active indicator (Amber)
Door Open This Car Indicator	Indicator light	Active indicator (Amber)
Windshield Defroster in Use Indicator	Indicator light	Inactive indicator (Amber)
Bypass in Use Indicator	Indicator light	Active indicator (Amber)
Spin/Slide Indicator	Indicator light	Active indicator (Amber)
Door Open Other Cars Indicator	Indicator light	Inactive indicator (Amber)

Windshield/Door Panel

Function	Switch Positions/Type	Representation
Parking Brake Switch	Three (3) momentary position rocker switch Apply/NO Input/Release	Active control (White)
Coupling Switch	Three (3) momentary position rocker switch w/guard Couple/No Input/Uncouple	Active control (White)
Crew Signal Switch	Three (3) momentary position rocker switch Crew Signal/Stop and Proceed	Active control (White)
Defrost	Two (2) permanent position rocker switch On/No Input	Inactive control (White)
Washer	Two (2) momentary position rocker switch Washer/No input	Inactive control (White)
Wiper Speed Control	Knob rotary switch	Inactive control (White)
Rear (Right Side Doors) Switch	Three (3) momentary position toggle switch Open/No Input/Closed	Active control (Silver)
Full/Half (Right Side Doors) Switch	Two (2) permanent position toggle switch Full/Half	Active control (Silver)
Front (Right Side Doors) Switch	Three (3) momentary position toggle switch Open/No Input/Closed	Active control (Silver)

Lighting/Communication Panel

Function	Switch Positions/Type	Representation
Cab Lighting Switch	Three (3) permanent position rocker switch White/Off/Red	Inactive control (White)
End Lighting Switch	Three (3) permanent position rocker switch Farebox/Off/Doors	Inactive control (White)
Interior Lighting Switch	Three (3) momentary position rocker switch On/No Input/Off	Inactive control (White)
Car Wash Switch	Two(2) permanent position rocker switch On/Off	Active control (White)
Fault Reset Switch	Two (2) momentary position rocker switch Fault Reset/No Input	Active control (White)
Recharge Switch	Two (2) momentary position rocker switch Recharge/No Input	Active control (White)

Radio Switch	Two (2) momentary position rocker switch Radio/No Input	Active control (White)
Speaker Selection Switch	Three (3) permanent position rocker switch Exterior/Interior/All	Inactive control (White)
PA/IC Switch	Three (3) momentary position rocker switch PA/No Input/Intercom	Inactive control (White)

Emergency Stop/Power Changeover Panel

Function	Switch Positions/Type	Representation
Emergency Stop	Two (2) position push button Off/On	Active control (Red)
Power Change Over Switch	Three (3) position rotary selector switch Pantograph/Third Rail/Isolate	Active control (Black)
Headlight Switch	Three (3) permanent position rocker switch High/Low/Off	Active control (White)
Horn/Sand Switch	Two (2) momentary position switch Horn/Sand	Active control (White)

Left Side Console

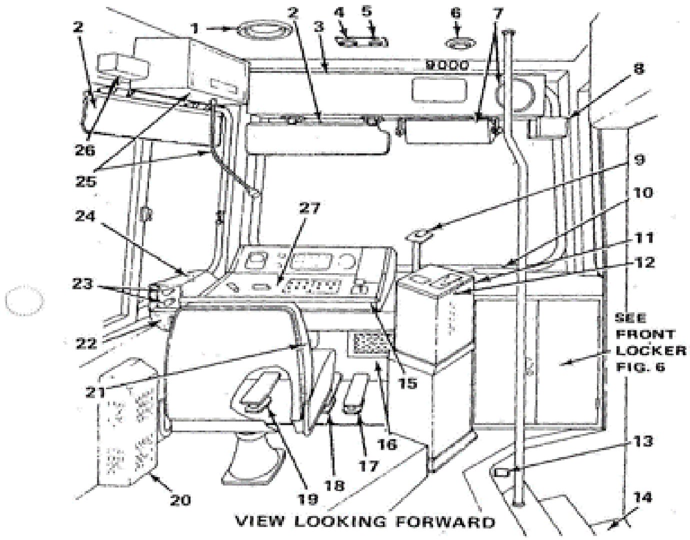
Function	Switch Positions/Type	Representation
Cab Display Dimmer Switch	Rotary knob selector switch	Inactive control (Black)
Fault Display Switch	Two (2) momentary position rocker switch On/No Input	Active control (White)
Cab Light Dimmer Switch	Rotary selector switch	Inactive control (Black)
Rear (Left Door) Switch	Three (3) momentary position toggle switch Open/No Input/Closed	Active control (White)
Front (Left Door) Switch	Three (3) momentary position toggle switch Open/No Input/Closed	Active control (White)
Snow Brake Switch	Three (3) momentary position toggle switch On/No Input/Off	Active control (White)
Evacuation Lights Switch	Three (3) momentary position toggle switch On/No Input/Off	Inactive control (White)
Cab Signal Switch	Two (2) permanent position rocker switch	Active control (White)
Cab Heater Selector Switch	Five (5) position rotary selector switch Fan Only/Off/Low/Medium/High	Inactive control (Black)

Not in reach while operating the simulator

Function	Switch Positions/Type	Representation
Traction Motors A-End Cutout	Two (2) position switch sealed in cut-in position Cut-in/Cutout	Active control
Traction Motors B-End Cutout	Two (2) position switch sealed in cut-in position Cut-in/Cutout	Active control
Regenerative Braking Cutout	Two (2) position switch sealed in cut-in position Cut-in/Cutout	Active control
ATC Cutout	Two (2) position rotary selector switch	Active control

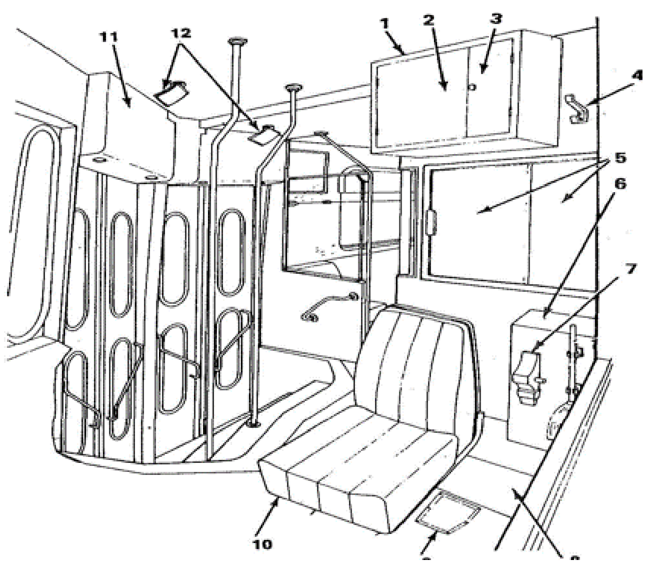
2.3.5 Single and Double End LRVs

The following diagrams are provided for reference:



CAB AREA (FRONT)

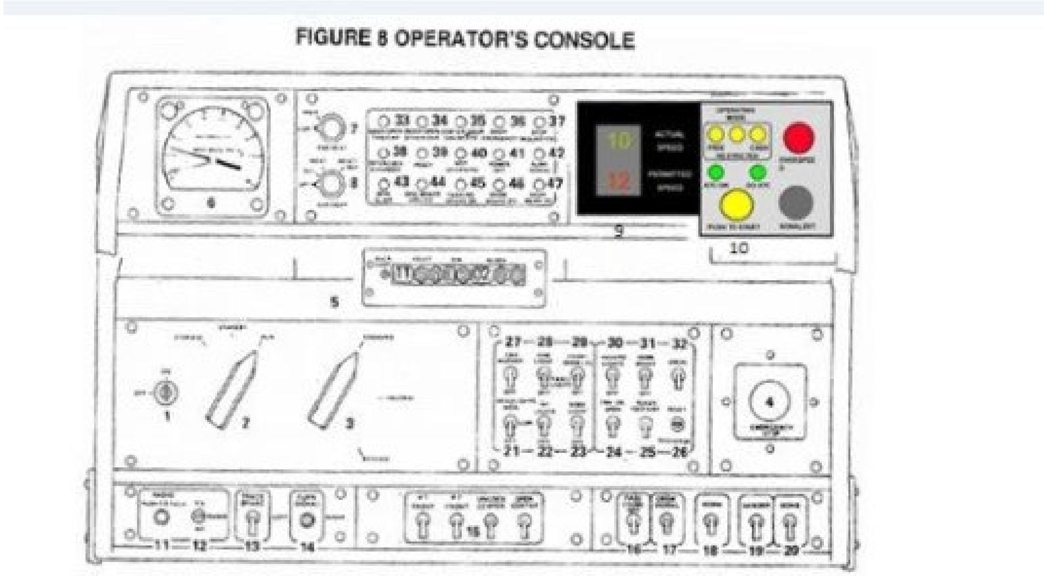
1. AIR DIFFUSER
2. SUN VISOR
3. DEST SIGN
4. PANEL LIGHT
5. CAB LIGHT
6. FRT DOOR LIGHT
7. REAR MIRROR
8. BLOCK SIGN
9. TRNSFR CUTTER
10. DEFROSTER
11. FARE BOX
12. SWITCH IRON
13. STEPWELL LIGHT
14. STEP DEICER
15. TRASH BAG CLIP
16. CAB HEAT VENT
17. POWER PEDAL
18. BRAKE PEDAL
19. SAFETY PEDAL
20. CAB HEATER
21. HELP LIGHT SWITCH
22. PARK BRAKE CONTROL
23. WIPER CONTROL
24. OUTSIDE DOOR SWITCH
25. COMMUNTCATIONS CONTROL UNIT W/MIKE
26. STOP REQUEST CHIME
27. OPERATOR'S CONSOLE



CAB AREA REAR VIEW

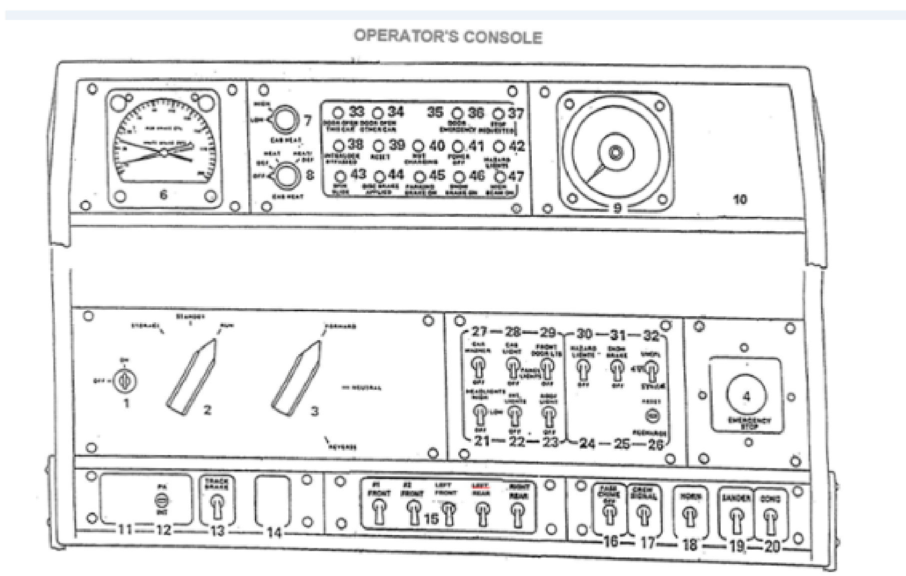
1,2,3. OPERATOR'S LOCKER
4. COAT HANGER
5. NIGHT PANEL
6. CIRCUIT BREAKER PANEL (REAR)
7. WHEEL CHOCK
8. LOW VOLTAGE RELAY PANEL
9. ACCESS COVER FOR BLOWER
10. CAB SEAT
11. DOOR ENGINE COMPARTMENT COVER
12. STEPWELL MIRRORS

Cab Area General Arrangement



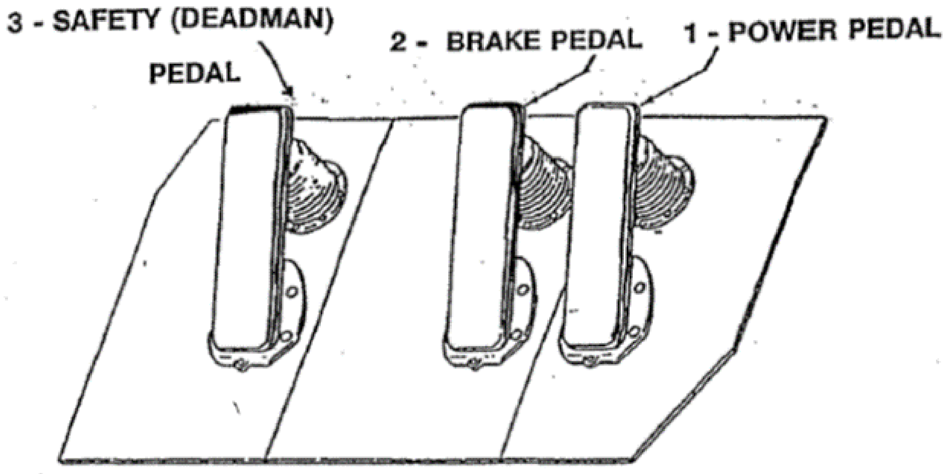
1. Key Switch
2. Mode Switch
3. Direction Switch
4. Console Emergency Stop
5. Vetag ID
6. Air Gauge
7. Cab Heater Upper
8. Cab Heater Lower
9. Speedometer
10. CBTC Indicators/Buttons
11. Radio
12. PA
13. Track Brake
14. Turn Signal
15. Doors
    - #1 Front
    - #2 Front
    - Unlock Center
    - Open Center
16. Pass Chime
17. Crew Signal
18. Horn
19. Sander
20. Gong
21. Headlights
22. INT Lights
23. Roof Lights
24. TRK SW Open
25. Ready To Start
26. Reset/Recharge
27. Car Wash
28. Cab & Panel Lights
29. Front Door Lights
30. Hazard Lights
31. Snow Brake
32. Uncouple
33. Door Open This Car
34. Door Open Other Car
35. Center Door Unlock
36. Door Emergency
37. Stop Request
38. Interlock Bypassed
39. Reset
40. Not Charging
41. Power Off
42. Turn Signal
43. Spin/Slide
44. Disc Brake Applied
45. Parking Brake On
46. Snow Brake On
47. High Beam

Operator's Console (Single End configuration)



1. Key Switch
2. Operation Mode Switch
3. Direction Mode Switch
4. Console Emergency Stop
5.
6. Air Gauge
7. Cab Heater Upper
8. Cab Heater Lower
9. Speedometer
10.
11.
12. PA Address & Intercom
13. Track Brake
14.
15. Doors
    - #1 Front
    - #2 Front
    - Left Front
    - Left Rear
    - Right Rear
16. Pass Chime
17. Crew Signal
18. Horn
19. Sander
20. Gong
21. Headlights
22. Interior Lights
23. Roof Lights
24.
25.
26. Reset/Recharge
27. Car Wash
28. Cab or Panel Lights
29. Front Door Lights
30. Hazard Lights
31. Snow Brake
32. Coupler Switch
33. Door Open This Car
34. Door Open Other Car
35.
36. Door Emergency
37. Stop Reset
38. Interlock Bypassed
39. Reset
40. Not Charging
41. Power Off
42. Hazard Lights
43. Spin/Slide
44. Disc Brake Applied
45. Parking Brake On
46. Snow Brake On
47. High Beam

Operator's Console (Double End configuration)



Pedal Configuration

Cab controls and indicators to be included in both LRV Training Simulator configurations:

Operator's Console

Function	Switch Positions/Type	Representation
Key Switch	Two (2) position rotary key switch On/Off	Active control
Mode Switch	Three (3) position rotary switch Storage/Standby/Run	Active control
Direction Switch	Three (3) positon rotary switch Forward/ Neutral/Reverse	Active control
Console Emergency Stop	Pushbutton	Active control (Red)
Air Gauge	Two (2) needle pressure gauge Red (brake cylinder), White (emergency pipe)	Active Indicator
Cab Heater Upper	Two (2) position rotary switch Low/High	Inactive control
Cab Heater Lower	Four (4) position rotary switch Off/Def/Heat/Heat&Def	Inactive control
PA	Three (3) momentary position toggle switch PA/No Input/INT	Active control
Track Brake	Two (2) permanent position toggle switch On/Off	Active control
#1 Front Door	Two (2) permanent position toggle switch Open/Close	Active control (touchscreen permitted)
#2 Front Door	Two (2) permanent position toggle switch Open/Close	Active control (touchscreen permitted)
Pass Chime	Two (2) momentary position toggle switch Cancel/Active	Active control
Crew Signal	Two (2) momentary position toggle switch On/Off	Active control
Horn	Two (2) momentary position toggle switch On/Off	Active control
Sander	Two (2) momentary position toggle switch On/Off	Active control

Gong	Two (2) momentary position toggle switch On/Off	Active control
Headlight	Three (3) permanent position switch High/Low/Off	Active control
Int Lights	Two (2) permanent position toggle switch On/Off	Inactive control
Roof Light	Two (2) permanent position toggle switch On/Off	Inactive control
Reset/Recharge	Three (3) momentary position toggle switch Reset/No Input/Recharge	Active control
Car Wash	Two (2) permanent position toggle switch On/Off	Active control
Cab/Panel Light	Three (3) permanent position toggle switch Cab Lights/Panel Lights/Off	Inactive control
Front Door Lights	Two (2) permanent position toggle switch On/Off	Inactive control
Hazard Lights	Two (2) permanent position toggle switch On/Off	Active control
Snow Brake	Two (2) permanent position toggle switch On/Off	Active control
Door Open This Car	Indicator light	Active indicator (Amber)
Door Open Other Car	Indicator light	Active indicator (Amber)
Door Emergency	Indicator light	Active indicator (Red)
Stop Request	Indicator light, solid for request, flashing with door open, accompanied by chime sound.	Active indicator (Green)
Interlock Bypassed	Indicator light	Active indicator (Amber)
Reset	Indicator light	Active indicator (Red)
Not Charging	Indicator light	Active indicator (Red)
Power Off	Indicator light	Active indicator (Red)
Spin/Slide	Indicator light	Active indicator (Amber)
Disc Brake Applied	Indicator light	Active indicator (Amber)
Parking Brake On	Indicator light	Active indicator (Amber)
Snow Brake On	Indicator light	Active indicator (Amber)
High Beam On	Indicator light	Active indicator (Amber)

Cab Area

Function	Switch Positions/Type	Representation
Microphone	Gooseneck microphone with built in push to talk button	Active control
Parking Brake	Two (2) permanent position lever Released/Applied	Active control

Operator Foot Controls

Function	Switch Positions/Type	Representation
Power Pedal	Foot pedal	Active control
Brake Pedal	Foot pedal	Active control
Safety Pedal (Deadman)	Foot pedal	Active control

Not in reach while operating the simulator

Function	Switch Positions/Type	Representation
Motor Cutout	Five (5) position rotary selector switch All Out/3 4 Out/All In/ 1 2 Out/ All Out	Active control
Disc Brake Cutout #1 Cutout Box	Two (2) position covered switch Cut-in/Cutout	Active control
Disc Brake Cutout #2 Cutout Box	Two (2) position covered switch Cut-in/Cutout	Active control
ATC Bypass	Two (2) position selector switch sealed in normal position Normal/Bypass	Active control
Door Interlock Bypass	Two (2) position covered switch Cut-in/Cutout	Active control
Zero Speed Interlock Bypass	Two (2) position covered switch Cut-in/Cutout	Active control

Cab controls and indicators to be included exclusively in Single End LRV Training Simulator configurations:

Note: these controls and indicators shall be represented on a display or touch screen in order to facilitate different configurations upon loading.

Operator’s Console

Function	Switch Positions/Type	Representation
VETAG ID	Pushbuttons & LED indicators, display only with values changeable by instructor.	Active display
Communication Based Train Control System (CBTC)	Cab signaling system, contains display and “Push to Start” pushbutton.	Active display with yellow pushbutton control
Radio (Push to Talk)	Pushbutton	Inactive control (Red)
Turn Signal	Three (3) permanent position toggle switch Left signal/Off/Right signal	Active control
Unlock Center Door	Two (2) permanent position toggle switch Unlock/Lock	Active control
Open Center Door	Two (2) permanent position toggle switch Open/Close	Active control
TRK SW Open	Not Used	Inactive control
Ready to Start	Not Used	Inactive control
Uncouple	Pull up to operate two (2) momentary position toggle switch with guard cover (Red) Uncouple/No Input	Active control
Center Door Unlocked	Indicator Light	Active indicator (Amber)
Turn Signal	Indicator light accompanied by sound	Active indicator (Green)

Cab controls and indicators to be included exclusively in Double End LRV Training Simulator configurations:

Note: these controls and indicators shall be represented on a display or touch screen in order to facilitate different configurations upon loading.

Operator's Console

Function	Switch Positions/Type	Representation
Speedometer	Analog dial representing MPH (0-60) & KPH (0-100)	Active indicator
Left Front Door	Two (2) permanent position toggle switch Open/Close	Active control
Left Rear Door	Two (2) permanent position toggle switch Open/Close	Active control
Right Rear Door	Two (2) permanent position toggle switch Open/Close	Active control
Coupler Switch	Lift to operate three (3) permanent position toggle switch UNCPL/CTR/STORE	Active control

Not in reach while operating the simulator, or as approved by the Engineer

Function	Switch Positions/Type	Representation
Panto Raise	Momentary pushbutton (Green)	Active control
Panto Lower	Momentary pushbutton (Red)	Active control

2.3.6 Cab Signaling System General Description

The cab signaling systems shall enforce the safe operation of the train primarily through overspeed protection. Each system can initiate a penalty brake application in order to stop the train if the operator is unable or unwilling to do so.

Cab signaling system equipment shall be designed for use and compatibility with the territory which it operates on.

User input to the system shall come from devices within the Operator's cab. Normally, input can only be produced from an activated cab which occurs when the cab is made up as the lead cab in the consist. In order to accomplish its control tasks, the equipment interacts with other systems on the vehicle, such as the air brake and the vehicle control systems.

The Contractor shall supply all necessary devices, cutouts, interfaces, etc., to provide a complete functional system within the simulator environment.

2.3.6.1 Cab Signaling System Requirements

The cab signaling systems shall conform to all SEPTA City Transit Division rules and regulations.

All cab signaling system functional items shall be modeled in the simulator and shall be fully configurable, including fault and failure modes, within any training exercise or scenario.

SEPTA shall supply all relevant information to ensure the Contractor has sufficient knowledge and understanding of the cab signaling system functionality to integrate this system into the Training Simulator environment while complying with the requirements of the technical specification.

2.3.6.2 M-4 Cab Signaling System Functions

The M-4 ATC equipment uses track receivers to continuously monitor coded carrier signals in the rail. Coded carrier information is translated to signal aspect information, which is used for traffic control. This information shall be simulated to convey the appropriate information to the Trainee and shall be integrated into the training exercises and scenarios.

The ATC system shall perform the following functions:

1. Simulate the block signal information transmitted from the running rail into the active cab of the train and shall enforce the speed limits associated with the signal information received.

2. Incorporate one (1) Speedometer/Cab Signal Display Unit, in each cab.

3. Allow operation at speeds up to 30 MPH when the ATC Cutout Switch is utilized.

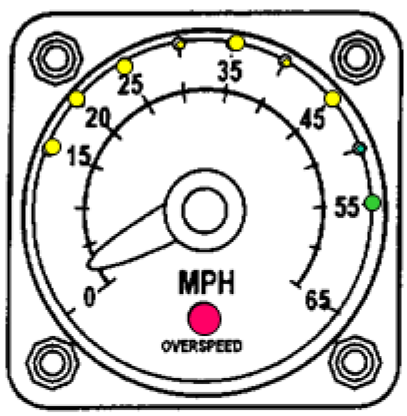
4. Incorporate Stop and Proceed button functionality. Activating the Stop and Proceed button at speeds 1 MPH or less shall change the cab speed code to restricted speed until a more favorable code is received. The switch is also used to silence the audio alarm, reset the cab signal/automatic train control, and allow train movement when the master controller mode switch is placed in the RUN position.

5. Enforce a penalty brake as defined by the SEPTA ATC System .

6. Perform an automated departure test when activated.

The ATC system shall enforce the following speed codes:

- No Code (0 MPH)
- Restricted Speed (15 MPH, flashing code, intermittent audible tone)
- 15 MPH
- 20 MPH
- 25 MPH
- 35 MPH
- 45 MPH
- 55 MPH



M-4 Speedometer/Cab Signal Display Unit

The M-4 simulators shall include stop arm functionality. Stop arms shall be located at interlocking signals and shall be active ("up") when its associated interlocking signal is set to stop. Passing an active stop arm shall result in a penalty brake application. The instructor shall have the ability to select the state of stop arms (automatic, "up" (active), "down" (inactive)).

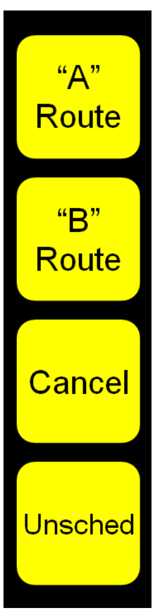
2.3.6.3 B-4 Cab Signaling System Functions

The B-4 simulators shall include stop arm functionality. Stop arms shall be located at all signals and shall be active ("up") when its associated interlocking signal is set to stop. Passing an active stop arm shall result in a penalty brake application. The instructor shall have the ability to select the state of stop arms (automatic, "up" (active), "down" (inactive)). The operator shall have the ability to change the state of the stop arm to "down" (inactive) through use of the Train Stop Arm Release switch. The Train Stop Arm Release switch shall not be in reach of the operator while in a seated position and shall only be functional when the train is at standstill at a non-interlocking signal.

The B-4 simulators shall include the Automatic Vehicle Identification System (AVI). AVI ID buttons shall be functional. When the train is directly over the AVI loop, AVI ID buttons shall illuminate and be functional. The use of AVI ID buttons shall accurately alter switch routing and wayside signaling. Instructors shall have the ability to change displayed block numbers and routing codes.

The following AVI ID inputs shall be simulated:

- "A" Route Button – Right Route
- "B" Route Button– Left Route
- Cancel Button – Drops the signal to "Stop"
- Unsched Button – Unscheduled Train Switch
- Block Number – Display changeable by instructor
- Routing Code – Display changeable by instructor



AVI Buttons

Block Number **Routing Code**

2.3.6.4 N-5 Cab Signaling System Functions

The N-5 ATC equipment uses track receivers to continuously monitor coded carrier signals in the rail. Coded carrier information is translated to signal aspect information, which is used for traffic control. This information shall be simulated to convey the appropriate information to the Trainee and shall be integrated into the training exercises and scenarios.

The ATC system shall perform the following functions:

1. Simulate the block signal information transmitted from the running rail into the active cab of the train and shall enforce the speed limits associated with the signal information received.

2. Incorporate one (1) Speedometer/Cab Signal Display Unit, in each cab.

3. Allow operation at speeds up to 35 MPH when the ATC Cutout Switch is utilized.

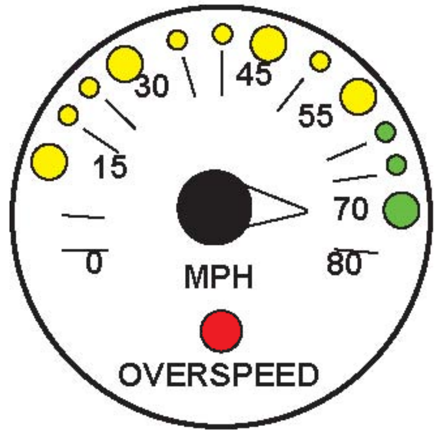
4. Incorporate Stop and Proceed button functionality. Activating the Stop and Proceed button at speeds 1 MPH or less shall change the cab speed code to restricted speed until a more favorable code is received. The switch is also used to silence the audio alarm, reset the cab signal/automatic train control, and allow train movement when the master controller mode switch is placed in the RUN position.

5. Enforce a penalty brake as defined by the SEPTA ATC System .

6. Perform an automated departure test when activated.

The ATC system shall enforce the following speed codes:

- No Code (0 MPH)
- Restricted Speed (15 MPH, flashing code, intermittent audible tone)
- 15 MPH
- 20 MPH
- 25 MPH
- 35 MPH
- 45 MPH
- 55 MPH
- 70 MPH (Provisioned speed, currently unused)



N-5 Speedometer/Cab Signal Display Unit

2.3.6.5 Single End LRV Cab Signaling System

The Single End LRV CBTC system uses communication between cars and the wayside to monitor positional information for all cars in CBTC operating territory. Positional information relative to other cars is used to determine maximum operating speed, which is used for traffic control. This information shall be simulated to convey the appropriate information to the Trainee and shall be integrated into the training exercises and scenarios.

The CBTC system shall perform the following functions:

1. Simulate the information transmitted from the wayside into the active cab of the train and shall enforce the speed limits associated with the signal most restrictive of the calculated speed limit information received and existing civil speed limits. The calculation of speed limits based on position relative to other LRVs shall be simulated.

2. Incorporate one (1) CBTC Operator’s Panel, in each cab.

3. Allow operation in Restricted Speed mode (speeds up to 20 MPH) when a cab signal failure occurs. Restricted Speed mode will not allow movement after the initial stop unless the Push to Start button is utilized.

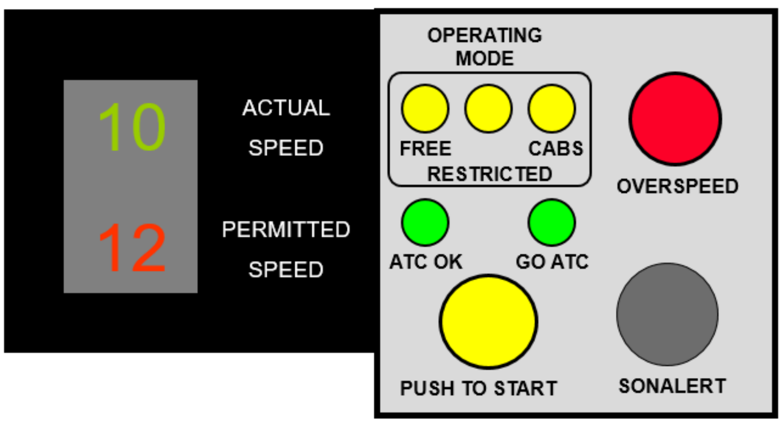
4. Incorporate Push to Start button functionality. Activating the Push to Start button allows the vehicle to move after the initial stop while in Restricted Speed mode.

5. Incorporate ATC Bypass Switch functionality. Activating the ATC Bypass Switch causes the permitted speed and operating mode indicators to go dark and will not enforce speed limits (speed limits enforced by rule only).

6. Enforce a penalty brake as defined by the SEPTA CBTC/ATC System. This shall include passing a red signal at initialization and interlocking signals.

7. Perform an automated initialization test when activated.

8. Perform an automated departure test when activated.



Single End LRV CBTC Operator's Panel

2.3.6.6 Double End LRV Cab Signaling System

By default, the LRV simulator shall have no cab signaling system present while the simulator is in the Double End configuration. A provision shall be included to allow the instructor to enable the CBTC system model used in the Single End configuration for the Double End configuration. Enabling the CBTC system shall replace the Speedometer present on the touch screen with the CBTC Operator's panel present in the Single End configuration. The Instructor's Workstation software shall have sufficient tools provided to model CBTC functionality on Trolley Lines Routes 101 and 102.

2.3.6.7 Departure Test

A departure test is a sequence of cab test functions that are performed to verify the operational integrity of the equipment as well as external control devices and operator controls and indicators. The provided cab signaling systems shall include provision for departure tests that are sufficient in scope and design so as to meet all requirements as currently mandated by the SEPTA City Transit Division Operating Rules and Special Instructions.

If all prerequisite entry conditions are met, the following will initiate a cab signaling system departure test:

- M-4: Pressing and holding the ATC TEST switch until all indicator lights on the speedometer/cab signal display unit come on.
- N-5: Moving the cab signal test switch to the ON position.
- Single End LRV (and provisioned CBTC model for Double End LRV): Entering designated track area.

SEPTA will provide details on the required prerequisite conditions and operational responses for all cab signaling system departure tests.

2.4 TECHNICAL REQUIREMENTS

The information provided and the works produced during the process of fulfilling the requirements of this specification including but not limited to all sound recordings, images, multimedia, video recordings and computer generated imagery are owned, except as otherwise expressly stated, by Southeastern Pennsylvania Transportation Authority ("SEPTA"). Except as otherwise expressly stated herein, they may not be copied, transmitted, displayed, performed, distributed (for compensation or otherwise), licensed, altered, framed, stored for subsequent use or otherwise used in whole or in part in any manner without SEPTA's prior written consent.

2.4.1 Visual System

The imaging for all simulators shall simulate subterranean, elevated, and at grade rail traffic and include stations and other features found within the SEPTA system. The view developed by the Contractor shall give the Trainee a realistic perception as close as possible to real operating conditions.

High quality, commercially available image generators shall be used to render the graphic images displayed by the visual simulation. The image generators shall incorporate state-of-the-art processors and shall be expandable and/or upgradeable to support emerging technology advances of video components. Upgrades shall be completed by replacing video card components and/or expanding the video memory.

2.4.2 CGI Images

The forward view shall consist of a commercially available, high quality, full color, flat panel display and shall be appropriately sized to represent a realistic presentation of the visual simulation. The flat panel display shall provide an undistorted horizontal and vertical field-of-vision. The display shall meet or exceed the following requirements:

1. Resolution of 1024 by 768
2. 60 Hz update rate
3. Refresh rate of 60 Hz non-interlaced
4. Anti-aliasing 8 x 8 minimum
5. Provide flicker free graphics for the complete range of driving speeds from stationary to 100 mph.

2.4.3 CGI Modeling Database

The real-time CGI images shall allow runs on the modeled tracks in both directions.

The eye point location and attitude, used to compute the image, shall be placed at the standard position of the operator's eyes in the locomotive and move accordingly to the interface computer requirements. The head pitch and roll of the view shall depend on the curvature, gradient, and superelevation of the track.

All images and objects shall be modeled in accurate high fidelity graphics so as to provide a representation of the actual environment. The following areas shall be CGI modeled with images that faithfully and accurately reflect the physical characteristics of the right-of-way and the adjacent landscape:

- All Interlockings between opposing distant signals; or when not present, code change points.
- All Stations between opposing braking points.

All other portions of the right-of-way and adjacent areas may be modeled through the use of graphics that accurately represent the type of landscape and geography with corresponding generic style graphics.

All objects shall be textured and available with different levels of detail (up to 4 levels). Representation of images shall be true to scale with correct orientation and movement in all cases and shall accurately represent all existing physical right-of-way characteristics. All images shall be clearly visible and their texture, shape, size, position, orientation and movement shall be correct under all conditions, including:

- A large number and variety of three-dimensional objects.
- Correct and proper perspective and geometric mass of all objects.
- Correct adjacent concealment of three-dimensional objects, as required.

- Representation of ground relief, inclines, protrusions, dips, etc.
- Presentation of buildings, obstacles, trees, hills, and other objects with sufficient detail to enable determination of relative position.

Visibility distance shall be three (3) miles, variable with size of objects and environmental conditions. The field of view shall be consistent the cab front window.

Elements to be modeled shall include, but are not limited to:

- All trackage (including yards, loops, and sidings), signal systems, third rail (where present), and catenary (where present) covering the territory described in Section 2.2.7.
- All grade and pedestrian crossings, bridges, overpasses, underpasses, and culverts.
- Adjacent passenger equipment on mainlines, yards, loops, and sidings.
- Animated pedestrians, road traffic, track cars, and other passenger trains shall be included in the simulation.
- Animated in place passengers upon and around platforms, station areas and crossings. Animated C&S, B&B, ET, and Track Department personnel in and around track area performing duties.
- The ability to simulate the operation of track cars, temporary signals and signs, barricades, and roadway workers shall be provided.
- Particular attention must be made to ensure that lighting and visibility conditions presented in tunnels are as realistic as possible.
- Environmental changes including weather events, seasonal foliage changes, slippery rail conditions, intermittent wire and third rail contact, angle of sun relative to time of day, reduced visibility, etc. Slippery rail conditions from foliage shall be shown on the tracks in the CGI for predefined zones of track. The activation of the modified track condition and its appearance in the CGI shall be controlled by the instructor for each predefined zone.

The ability to start simulations from any yard, station, intermediate terminal, or outlying point shall be possible, as well as the ability to configure simulations to run though from one point to any another location without having to pause to load a new route file.

2.4.3.1 Trackage

All tracks (including all yard tracks and sidings), switches, derails, catenary, third rail, interlockings, signs, and signals within SEPTA’s City Transit Division operating territory are to be modeled faithfully and accurately, without exception. It shall be possible to add, remove, relocate, and reconfigure functionality of derails within the Scenario Development authoring software environment. It shall be possible to set all switches to “normal’ and “reverse”. Turnouts and switches between tracks shall be fully modeled; the actual position of the points shall be changeable on-line, in real-time, by the instructor or specified as an event to be automatically executed during a simulation based on selected conditions of the simulation.

All other appliances associated to City Transit Division operations shall be modeled. Examples include, but are not limited to, mileposts, signage, stop arms, rail lubricators, station stop markers, fouling points, whistle boards, dragging equipment detectors, hotbox detectors, crossing indicators, switch heaters, etc. These elements shall be fully functional, controllable, and reconfigurable. It shall be possible to add, remove, relocate and reconfigure functionality of elements such as railroad flags (i.e. blue, restricted, green, red, yellow, etc.), railroad signs (i.e. whistle boards, stop, working limits, etc.), maintenance of way equipment, track personnel, stop banners, broken rails, fusees, and portable derails within the Scenario Development authoring software environment.

2.4.3.2 Catenary and Third Rail

All catenary and third rail including section breaks, air gaps, and phase breaks, support structures, signal lines, transmission lines, lineside poles, associated signage, and substations covering the operating territory described in this Specification shall be modelled. It shall be possible to reduce catenary and third rail voltage or de-energize any and all sections of catenary and third rail on-line, in real-time by the instructor or specified as an event to be automatically executed during a simulation based on selected conditions of the simulation.

2.4.3.3 Wayside Signals

The signals placed along the route shall be from a library which includes all current signal configurations as employed by SEPTA. All signal aspects will displayed be accordance with SEPTA City Transit Division Operating Rules and Special Instructions. Signal aspects displayed shall conform to accurately represent these operations without exception. Signals shall be capable of being changed once a training exercise has been started, and be capable of:

- Being blacked out (simulating a non-lit condition).
- Being displayed in a non-conforming manner.
- Being displayed with an imperfect aspect.

The signal displays shall be controllable in the following manner:

- Controllable by the instructor in real time.
- Specified as an event to be automatically executed during a simulation based on selected conditions of the simulation.
- Change in accordance with the movement of the simulated train or other trains which operate in the simulation.

It shall be possible to modify signal states within the Scenario Development authoring software environment.

2.4.3.4 Grade Crossings

All grade crossings shall be modeled as an accurate representation of actual locations. This applies to at all crossings, including: Road, Rail, Pedestrian, and Trail crossings. Track circuitry shall be accurately modeled to cause lights to flash and gates to operate as they would normally. It shall be possible to add, remove, relocate, and reconfigure functionality of these elements within the Scenario Development authoring software environment.

2.4.3.5 Stations

Stations on the route shall be modeled as accurate representations of actual locations. Imagery shall include, but are not limited to, the following features:

- Platforms, railings and seating.
- Adjacent Trackage.
- Intertrack Fencing (where applicable).
- Platform Step-ups.
- Mini-High Platforms.
- Intervening Tracks.
- Inner Track Low Level Platforms.
- Train placement markers.
- Station signage.
- Stairs.
- Pedestrian Crossings.
- People on Platforms (different density to be available).

2.4.3.6 Other Features to be Modeled

Other features to be modeled include:

- All bridges, culverts, and underpasses along the right-of-way shall be modeled.
- Tunnels shall be modeled and include lighting, tunnel walls, and tunnel equipment.
- Bushes, trees, and forests shall be placed on the surface textures to aid the impression of motion. A minimum of ten (10) different textured elements shall be modeled.
- Landmarks - Key landmarks such as specific buildings, water towers, factories, etc., along the routes shall be accurately modeled.
- Distinct geological formations.
- Water surfaces and features shall be modeled.
- The sky shall be modeled according to the weather, time, and obstacles to visibility.
- Buildings existing along the real track shall be included in the CGI database and shall be modeled faithfully and accurately.

- A minimum of twenty-five (25) generic buildings shall be modeled and included in the library.

It shall be possible to add, remove, relocate, and reconfigure functionality of these elements within the Scenario Development authoring software environment.

2.4.3.7 Environmental Effect Modeling

Weather conditions shall be reproduced including sun, fog, rain, and snow. The simulated weather shall be changeable from fine through moderate to bad. Rain shall be shown as falling in the image and shall have different densities/severities. Rain when selected shall result in a wet looking scene. Like rain, the reproduction of snow shall include snow cover ground and objects and snow perceived as falling. Different levels of visibility from 0% to 100% shall be represented. It shall be possible to alter the environmental effects, in real-time by the instructor or specified as an event to be automatically executed during a simulation based on selected conditions of the simulation.

The time of day and daylight shall be changeable gradually and be made in accordance with seasonal changes. A continuous transition from day to night shall be possible with all stages of twilight. The system shall also represent sun glare. The lighting of the scenery shall be calculated in real time taking into account the current light intensity, the visibility and weather conditions and the illumination of the surfaces. Therefore, a continuous alteration of visibility conditions that effect of the train's lights shall be simulated. Different lighting effects should be included: ambient light, platform light, train headlights of the simulated and other trains.

2.4.3.8 Animation

The following shall be represented as animated features by the proposed CGI:

- People shall add life and realism to the virtual scene. They shall be a placeable feature by the instructor to move along a predefined path and shall be animated where necessary with moving limbs. The path shall be defined by the instructor with three parameters: starting location, direction, and elevation. Each animated person or animal shall be designed with the fixed parameters: type of movement, a defined path (X, Y, and Z directions), and length of travel. A maximum distance (greater than 150 ft.) shall be determined during design phase. A list of people to be animated shall be submitted for approval by SEPTA. This list must include, at a minimum, SEPTA personnel providing various hand signals and operating hand-operated, dual-controlled or electric lock switches and fixed derails.
- People on platforms shall be represented in positions common to people waiting for a train. Positions shall be selected randomly.
- Passengers embarking and disembarking the simulated train. Door state and animation shall be simulated and shall be controllable by the operator using the door controls present in the simulator.

- Passengers falling into the track area. This event shall be controlled by the instructor.
- Passengers holding door open at a station. This event shall be controlled by the instructor.
- All train configurations as defined in TS 2.2.9 shall be modelled as trains moving along the track network both automatically and controllable by the instructor. These trains shall only be available on the lines which they operate on as defined in TS 2.2.7.
- Up to two per train simulator workstation type (M-4, B-4, N-5, and LRV for a total of up to 8) additional work or maintenance of way train configurations shall be modelled as trains moving along the track network controllable by the instructor. These trains shall only be available on the lines which they operate on. The available work or maintenance of way train configurations shall be determined and approved by SEPTA during design phase.
- Vehicular traffic including: automobiles, vans, SUVs, light trucks, motorcycles, straight trucks, tractor trailers, buses (both SEPTA & public school), bicycles and emergency vehicles (police, fire and ambulance services) crossing tracks shall be modeled.
- Vehicular traffic including: automobiles, vans, SUVs, light trucks, motorcycles, straight trucks, tractor trailers, buses (both SEPTA & public school), bicycles and emergency vehicles (police, fire and ambulance services) on roads visible from tracks shall be modeled.
- Vehicle traffic directly adjacent to and on trolley tracks shall be modelled for all Single and Double End LRV routes except for on dedicated rights of way. The instructor shall have the ability to enable, disable, and control the speed and direction of vehicle traffic on trolley tracks. Vehicle traffic adjacent to trolley tracks shall be automated.
- Trains crossing ahead of simulated train shall be modeled.

2.4.3.9 Removable and Moving Features

The following events shall be capable of being placed, moved or removed through an exercise or, in real-time, by the instructor:

- Other trains: A minimum of twelve (12) dynamic models (moving along the track) and 4 stationary models.
- Incorrect or unusual routes.
- Running in either direction on any track.
- Track workers and Transportation Department personnel.
- Passengers at stations requesting a stop.
- Permanent, temporary and emergency speed restrictions.
- Maintenance of way track vehicles and equipment.
- Animals or Trespassers on or along the right-of-way - Static & animated in place (minimum 4 separate models of each).
- Motor Vehicles on crossings - (minimum 6 separate models).
- Obstacle on or fouling track (minimum 12 separate models) (Chock, portable derail, fallen tree, slides, Burro Crane, washout, rolling stock, tire, shopping cart, bicycle, smoke, flooding, etc.).

The virtual environment shall support a number of variable conditions that can change or enhance the normal operating conditions of a training exercise or scenario. The Instructor shall be able to select, insert, and remove a variable condition or number of elements from a menu available from the Instructor's Workstation to be applied to a specific local location. The instructor shall have the ability to discretely activate the movement of a placeable element (e.g. motor vehicle, passenger, SEPTA personnel, animal, etc.) in a training exercise or scenario from the Instructor's Workstation and have the ability to activate predefined movement of any of these elements based upon triggering event(s) or conditions.

Discretely triggered movements of persons include, but are not limited to:

- Hand signal gestures (both with and without lantern/flag/sign).
- Manipulation of a ground thrown switch (both manual and dual-controlled).
- The application and removal of chock(s) or derail.

An Instructor utilizing a moveable feature to represent a person within a training exercise or scenario, shall have the ability to select the physical appearance this figure without restriction regarding race, age or gender.

2.4.4 Audio System

The cab simulator shall provide stereophonic audio feed-back to the Trainee. The sound shall be realistic and shall be at volumes consistent with the sound levels experienced in actual running on the route, and shall include the effects of acceleration and deceleration on these sounds.

The audio system shall use surround sound technology to convey the sound environment with a minimum of at least four high quality speakers positioned appropriately.

All sounds shall be correlated to Trainee action, vehicle operation, environmental conditions and images generated within the visual simulation.

The Doppler Effect shall be included to indicate the presence of nearby rail equipment, passing trains, or the passing structures and through tunnels.

2.4.5 Sound Library

The system shall be capable of reproducing up to 24 sounds simultaneously from a library of up to 60 sounds. This library shall include, but shall not be limited to, the following sounds:

- Cab/Train ventilation system.
- Acceleration and Brake sounds.

- Train/track sounds.
- Cab air sounds, cab warning indicators.
- Track clatter on joints, frogs, etc.
- Passing train noise related to length and velocity.
- Emergency brake.
- Air compressor.
- Wheel squeal in curves.
- Wheel creep.
- Flat spots.
- Train horn and bell.
- Coupling/Uncoupling.
- Pantograph and/or catenary failure.
- Third rail shoe and/or third rail failure.
- Weather Conditions (e.g. rain, wind, thunder, etc.).

2.4.6 Network Items

The Contractor shall install the Training Simulators and the instructor station at designated site (Simulator Training Facility). These simulators and instructor stations shall possess the ability to be linked to the Contractor for the purpose of updating simulation software, training materials, and Computer Generated Images (CGI). It shall also be possible to permit the Contractor to troubleshoot the simulators and instructor Workstations over the internet. The Contractor is responsible to supply any equipment and wiring required for digital communication and internet access.

2.5 MANAGEMENT OF SIMULATIONS

The instructor shall be provided with a simple mechanism for scenario (or exercise) creation. Each scenario (or exercise) shall allow for more or less automated training, needing either no or only a few actions by the Instructor.

At a minimum, it shall be possible to give the following attributes to the scenarios:

- Scenario name.
- Author.
- Level of difficulty.
- Scenario subject.
- Comments.

The system shall permit the management of scenarios. This function shall give access to the complete scenarios list, dedicated to a particular line, through which scenarios could be created, loaded, deleted, duplicated, modified, saved, or saved as. The ability to change scenario attributes during a training

session shall be included. It shall be possible to sort the list of scenarios by various attributes and to search for a particular scenario through an integrated screen based search utility.

The data that defines a scenario shall include at least:

- Initial conditions.
- Line on which the scenario operates.
- Selected route including position of switches.
- Train composition.
- Initial state of the train.
- Starting location and direction of the train.
- Status of all signals.
- Simulation time.
- Weather conditions.
- Passenger density on stations.
- Automatic train frequencies.
- Events, with the ability to trigger events on a specific condition, such as simulation time, train position, train speed. Events include:
    - Signal status changes (Wayside and Cab Signaling systems).
    - Switch status changes.
    - Control and placement of movable and removable objects.
    - Controlled and Automatic trains.
    - Changes in driving conditions (Adhesion levels, reduction in tractive effort, etc.).
    - Changes in environmental/atmospheric conditions.
    - Control and placement of faults on the train.
    - Warning messages.
    - Injection of CBT lesson module.

2.5.1 Instructor Interface

The instructor shall have the ability to control the simulator and prepare scenarios using a graphical man machine interface. This interface shall include the following functionalities:

- The Preparation Mode is to be used to prepare training sessions with scenarios and scoring templates (if applicable). It shall be possible to build and test scenarios on the Instructor Station without using a training Workstation. A specific interface must be provided to enable the Instructor to drive the scenario (with events and triggers) and to validate the scenario and make necessary changes. The scenario is then to be saved for training use in Simulation Mode.

- The Simulation Mode is to be used for operator training. The Instructor shall be able to use training scenarios built in Preparation Mode or to operate the simulator without using a prepared scenario. The ability for the Instructor to add or delete events during the running of

the scenario shall be predefined through the definition of access rights for the Instructor to add/delete events. If necessary, depending on his access rights, an Instructor shall be able to save a new scenario, without modifying or deleting the previous basic one.

The Instructor shall be able to load, save, save as, and manage scenarios. The loading time for a scenario shall not exceed one minute. The Instructor shall be able to define the external conditions when setting up a scenario. The initial simulated time shall be defined when setting up a scenario and clearly displayed to the Instructor.

Warning messages for the Instructor shall be displayed on the Instructor Station when a specified condition is met. The function is to enable the Instructor to be alerted when the simulation reaches a specified condition.

During a simulation, under circumstances determined by SEPTA, improper train operation or handling shall result in the immediate halting of the simulation, the freezing the image on the Training Simulator screen and a warning message to be sent to the Instructor Station. This action shall also prevent the simulation to be restarted or resumed by the Trainee by any means until it has been released by the controlling Instructor's Workstation.

The Training Simulator shall support the execution of Instructor initiated events that can be applied to a training exercise at any time. These events shall occur in real-time during the simulation to serve as changes to conditions, situations and equipment.

During a simulation, it shall be possible to freeze and then to restart the simulation from the point at which the simulation was stopped. The Instructor shall be able to restart a part of the saved scenario, as many times as needed and from different resumption points. It shall also be possible to return to a marker point for the replay of the simulation from a short time before such a point.

After a simulation, the replay mode shall allow the Instructor to replay a portion of a run or a complete run. For this, the Instructor shall be able to select a resumption point or a "marker-reminder point" and replay from that point. This shall give an exact replay functionality, playing again all the sounds (including the recorded operator intercom conversations), the train dynamics, the CGI track view, and the Train Management System. The replay shall not need any operator or Instructor action on the Desktop Simulator. It shall be possible to replay from a point as many times as the Instructor wants, until returning to simulation mode or quitting the simulator.

2.5.2 Instructor Interface Display

The following description illustrates the level of functionality which is required. Alternative solutions shall provide at least the same level of functionality.

1. Menu /Tool Bars

Extensive provision of drop down menus and icons shall be available to the Instructor to manage instructor interface functions.

2. Global Line View

   This display shall enable the Instructor to have an overview of a schematic layout enabling him to watch the entire line on which the operator is operating including:

   a. The names of the stations.

   b. The geographic location of the simulated train, symbolized with an arrow moving accordingly and pointing in the forward/reverse direction.

   c. The zone displayed on the Detailed Track View shall be highlighted.

3. Detailed Track View

   a. The displayed zone shall correspond to the zone contained in the highlighted area on the Global Line View. The Detailed Track View shall be the main operational area for Instructor interaction with the simulation session.

   b. In this zone, which shall display the complete view of the simulation status, the Instructor shall be able to operate and position track-related elements.

   c. It shall be designed for convenient operating and positioning, changes of infrastructure elements, route selection and train positioning.

   d. Operations shall be initialized by mouse "click" when positioned on a track or on a specific infrastructure element.

   e. The following controls are required as a minimum:

      1) Filter menu: to select the type of data displayed.

      2) Zoom in/out buttons.

      3) "Find train" mode: the Detailed Track View shall be positioned automatically following the simulated train position.

      4) Selected location mode: the Detailed Track View shall stay at a fixed location until moved manually by the Instructor.

4. Graphical Information and Commands

   The instructor shall be able to display the following information:

   a. Schematic Representation of the Track

   The Tracks shall be represented with:

      1) The track number or name and the direction of traffic.
      2) The presence and energized status of catenary.
      3) The status of the track (Out of Service, Work Zone, etc.).

4) The itineraries of the simulated train, controlled train and the automatic trains, all clearly distinguishable on the display.

b. Itineraries, Interlockings, Routes, Switches, Derails

Interlocking and Control Point names shall be displayed. The switch numbers and positions shall be displayed. Itineraries must be easily built, for example through the use of entry/exit route setting at each interlocking or control point, that sets all switch positions and all signal status. All Interlocking and Signaling System Rules and Special Instructions shall apply. The condition and position of hand operated and dual-controlled switches, and derails shall be indicated. It shall be possible to change the position of a hand operated or dual-controlled switch or derail by mouse "click" on the switch or derail and then via a configuration panel.

c. Station Platforms

Stations shall be capable of being represented with different passenger densities with an indication of the density indicated on the Instructor Station. The mile post of each station shall also be displayed.

d. Signals, Signs

The signal designations or numbers shall be displayed. The signaling logic shall be respected. The signs and signals shall be represented with specific icons on the track. The position shall indicate on which side of the track the sign is located. A representation of the signal aspect displayed on the CGI shall be displayed on the Instructor Station.

e. Configuration of Signals, Signs

It shall be possible to configure a signal or sign state by mouse "click" on the signal or sign and then via a configuration panel.

The Instructor shall have access to all controllable features and shall also be able to specify a command for a specific feature. Triggers on conditions shall be also possible.

f. Positioning of the trains

The positioning and the direction of the Simulated and Controlled trains shall be simple and capable of being achieved by a mouse "click". The positioning of the simulated train shall generate the following immediate effects:

1) The line symbolizing the simulated train on the Detailed Track View shall be updated

2) The 3D view shall be updated and display the 3D view at the new train position. It must be possible to use this function as a convenient way to check the visual aspect of the track including visual events at a specific location

3) In no case shall a switch position be altered by a repositioning of the simulated train.

g. Events

An event is a command executed by the Instructor on the track infrastructure or on the train.

1) The execution, modification, complete removal, delay of an event is to be immediate or conditional. Events shall be triggered on conditions, including external conditions generated by the operator.

2) Events which operate on track infrastructure (signals, switches, objects or people positioned on or near the track) shall be introduced by mouse "click" on the Detailed Track View. When active, a specific graphical icon shall be displayed at the corresponding track location. Each pending event shall have its own specific icon.

   a) For signals and switches, the specific icon shall be displayed adjacent to the object

   b) For faults on the train, the icon shall be displayed at the mile post position that will trigger it

The Instructor shall have the ability to choose the position of the removable objects with precision.

h. Faults on the train

1) It shall be possible to create simulated faults on the train through the MMI.

2) Faults shall be able to be set either:

   a. Immediately or

   b. On a time delay or

   c. At a specific track location specified by a "mouse click" on the Detailed Track View or

   d. On a trigger determined by a set of Instructor defined parameters.

i. Variables

1) The following variables shall be able to be input in real time, predefined in a scenario or held as a pending command:

   a) Rail head adhesion (controllable from 0 to 100%);

   b) Braking efficiency;

   c) Traction efficiency;

   d) Dynamic Brake efficiency;

   e) Brake Pipe Leakage; and

2) The train modeling (logic, dynamic performance, and braking system performance) must change accordingly.

j. Triggering conditions for events and commands

1) From the instructor station, the Instructor shall be able to manage triggering conditions. The triggering conditions for events shall be at least:

a) At a specified track location: The event shall start when the head of the chosen train (simulated or controlled) reaches the mile post defined by the Instructor;

b) After a specified time: The event shall start when the defined time delay has expired. It must be possible to define this delay in hours, minutes and seconds;

c) On a trigger: the event must start when one or more logic conditions are met (e.g.: door interlock indication, brake pipe pressure, speed, etc.). The variables used shall be selected from a predefined set of variables.

2) The three triggering conditions must be able to be used in conjunction with each other to trigger an event.

k. Discrepancies

1) Because definition of a scenario includes all control desk states, a discrepancy could occur when the position of the desk control is different from the one saved in the scenario. In this case, a list of all discrepancies must be displayed on the Instructor Workstation.

2) The Trainee will normally have to put the listed controls in a specific position to meet the scenario requirement. Then the simulation will allow the Trainee to start. However, the Instructor should have the ability to go through this discrepancy management to allow the Trainee to start even if certain conditions are not met.

l. Other Graphics

Graphics icons must show the position of tunnels, underpasses, bridges, and grade crossings.

m. Resumption Points

During a simulation session, the simulator shall automatically record the operator's and Instructor's actions. In addition, the simulator must store to hard disk periodically the full state of the simulation session (snapshot) and insert a specific icon. The track location at which the snapshots were recorded are called "Resumption Points". These resumption points shall be usable for "replay mode" or "restart mode".

n. Marker-Reminder points

In the event that a Trainee or the Instructor watching the simulation requires to go back to a particular point when replaying, the Instructor shall be able to insert manually a specific resumption point.

5. Track Information View

a. The track information view shall display the following to the Instructor :

1) Distance Scale: the distance scale must present the mile and parts of mile indications in the Detailed Track View;

2) Gradient scale: gradient shall be indicated as a ratio. A value shall be written depending on the orientation of the gradient, uphill or downhill;

b. Curvature scale: the curvature scale must indicate the value of curve radius

c. Both numerical value and graphical representation must be shown. Left and right curves must be easily recognizable.

6. Information Zone

a. This information zone, composed of one or more windows , shall be dedicated to the display of simulation information, including:

1) Malfunctions on infrastructure;

2) Trains;

3) Train faults;

4) Removable features;

5) Variables ; and

6) Pending events.

b. The lists must be automatically updated according to the simulation status. The Instructor shall be able to change events in accordance with their access rights within the scenario.

7. Status Bar

A status bar must group functions that do not relate to particular location on the track but rather with the train status or with data concerning the whole session:

a. Name: Operator name;

b. Line: Selected line;

c. Exercise: Name of active scenario;

d. Mode: Active Session Mode (Preparation Mode or Simulation Mode);

e. Simulated time; and

f. Train setting: Current simulated train configuration.

8. Multimedia and sound sequences

The Contractor shall provide a multimedia authoring tool to allow SEPTA employees to create multimedia sequences including sound text, pictures or video. Once the sequences have been created, the instructor shall have the ability to insert them into a scenario so that they are

played to the Trainee upon a set of triggering conditions. Simulator shall also provide sound recording capability so that different voice messages can be recorded by SEPTA employees, and then inserted by the instructor into a scenario in a similar way.

9. Trainee performance reports

a. End of Run Report

At the end of a simulation session a report shall be printed and stored as a file on the simulator. File reports shall be password protected to prevent alteration.

1) This report shall contain in a summary form, the details of the simulation session (operator's name, the scenario, the line, date & time).
2) The exercise history shall be available for the Instructor with the location and the simulated time for each event indicated.
3) All the faults, the Trainee's actions (emergency stop, dead man system, isolation switch or cock, braking, traction), other actions and events shall be traced.

b. Scoring Templates

1) Contractor shall propose to SEPTA a Trainee's assessment criteria available for the Instructor to compare Trainee's performance to a predetermined performance target (e.g.: train performance under Trainee control versus ideal performance). **[CDRL 2-01]** On completion of an exercise the instructor shall be able to print a complete report with Trainee's evaluation.

2) The scoring criteria shall include SEPTA Operating Rules, Special Instructions, Standard Operating Procedures, schedule adherence, station stopping accuracy, passenger comfort, energy efficient train handling, etc. Final design would be accomplished in consultation with SEPTA to provide any scoring tools tailored to SEPTA's needs.

3) The scoring report shall be fully customizable by SEPTA to set different performance levels or criteria (Scoring Templates). The content of this report, its format, and its level of customization shall be described in general in the proposal and then its design finalized and approved by the SEPTA during the project.

c. Off-line performance analysis station

The simulator system shall include an off-line performance analysis station which allows both Trainees and instructors to review details of simulation performance in a graphical and user-friendly manner.

2.5.3 Trainee Assessment

The Training Simulator shall have the capability to automatically score, record, and store Trainee compliance with all identified Operating Rules and signals, associated with proper train handling and operation, as well as the capability to record and report on energy consumption (efficiency) of train

handling for each Trainee. For Trainee and instructor review purposes, the simulator must provide the ability to replay the Trainees training/test run.

The Training Simulator shall generate a record of Trainee performance after the completion of each session. The record of Trainee performance shall include the following data:

1. Acceleration and coasting performance.
2. Speed limit adherence.
3. Braking performance.
4. Reaction to Instructor initiated events.
5. Schedule Adherence.
6. Energy consumption (efficiency).

The record of Trainee performance shall be searchable by:

1. Trainee name.
2. Employee number.
3. Employee position.
4. Training exercise or scenario.
5. Instructor name.
6. Date.

The Instructor's Workstation shall provide an input function to allow the Instructor to enter comments and additional observations into the Trainee performance record. A printed Trainee assessment report shall be printed when requested by the Instructor. The Trainee assessment report shall contain the Trainee performance data listed above.

The Trainee assessment report shall be saved as a record for each Trainee. Trainee performance records and Trainee assessment reports shall be stored in an integrated Standard Query Language (SQL) database located within the Data Administration Workstation and shall be accessible from the Instructor's Workstation. The database shall be large enough to store over 1,000 separate Trainee records and reports per year for a minimum of three (3) years. The Instructor shall be able to search, select, display and print Trainee records and reports from the Instructor's Workstations. The Instructor shall be able to archive and delete Trainee records and reports from the database using the Instructor's Workstations.

2.6 SCENARIO DEVELOPMENT WORKSTATION

The Scenario Development Workstation to be provided is PC based station which would have several LCD screens, which essentially duplicate each of the remote simulators with the exception of a physical control desk or cab and shall be integrated into the Instructors Workstation. The Scenario Development

Workstation would use a LCD screen control (desk) emulators, one for each of the four types of Training Simulators.

Training staff can use the Scenario Development Workstation and the Authoring Software to develop and test scenarios targeted for each simulator. Developed scenarios will be distributed to the simulators using the Data Administration Workstation.

2.7 RAIL EQUIPMENT MODELING

The simulation of the various SEPTA vehicles shall represent an accurate representation of real time performance of the cars of the SEPTA fleet. This includes the M-4, the B-4, N-5, Single End LRV, and Double End LRV. Acceleration and braking operations shall be implemented realistically and smoothly until the vehicle has come to a complete stop. All safety related systems including, but not limited to, Cab Signals, Cab Signaling Systems, Deadman Features, Passenger Emergency Intercom, and Door Summary, shall be modeled and shall include full and complete functionality. The proposed system shall be capable of modeling the train in all of the differing consist configurations as selected by the Instructor. The basic driving maneuvers shall be available as well as rescue maneuvers.

SEPTA shall provide all required vehicle characteristics, operation and control information, including but not limited to the following:

1. Cab assembly drawings indicating Trainee's cab equipment list and mounting arrangements and cab structural dimensions.
2. Cab layout drawings with details of cab equipment and illuminated displays and panels.
3. Functional description of each item of operator's cab equipment including operating voltage/current and protocol of the software and hardware interfaces for devices possessing digital intelligence.
4. Electrical circuit diagrams, circuit layout, and any microprocessor logic.
5. Description of rail equipment movement dynamics, control, and communication facilities.
6. Friction brake piping diagram and system functional descriptions.
7. Relevant brake system pressures for each passenger loading.
8. Compressor charging/discharging cycle times and cut-in and out pressures for pneumatics.
9. Gross and Net Weights and Vehicle lengths.
10. Tractive effort against speed curve.
11. Braking force against speed curve (dynamic, friction only, emergency).
12. Dynamic brake blending curves.
13. Energy consumption characteristics.
14. Regenerative braking data (e.g. line receptivity).
15. Traction motor current characteristics.
16. Number of motors per vehicle and their configuration.
17. Track Charts containing gradient and curve data.

2.7.1 Equipment Modeling

The following cab systems shall be modeled:

1. Cab Signaling systems as employed in the SEPTA City Transit Division System.
2. Air Brake Gauges.
3. Conductor’s Signal Buzzer.
4. Door Indicators.
5. Door Controls.
6. Radio System.
7. PA/IC System.
8. Communication Control Panel.
9. Deadman feature (if equipped).
10. Cab Displays (if equipped).
11. Headlight and Auxiliary Light controls and indicators.
12. Horn and Bell controls and cutout cocks.
13. Brake Valve.
14. Master Controller.
15. Loadmeter.
16. Fault Display Panels, Indicators, and Alarms.
17. Dynamic Brake Cutout.
18. Electro-Pneumatic Cutout.
19. Snow Brake Control.
20. End Door Bypass.
21. Pantograph Controls (if equipped).
22. Sander Controls (if equipped).
23. Uncoupling Control.
24. Emergency Brake Valve.
25. Penalty Magnet Valve Cutout.

Note: Controls or indicators vary upon equipment type.

2.7.2 Train Performance Parameters

The characteristics used to implement the model shall include, but shall not be limited to:

1. Instantaneous braking forces for each vehicle in the train.
2. Instantaneous traction forces at each axle.
3. Slack action caused by coupler characteristics.
4. Weight and load of the train (parameter changeable by the instructor in real-time during the simulation session or as a pre-recorded event).

5. Wind resistance.
6. Rolling resistance.
7. Static rolling resistance.
8. Forces caused by gradient and curvature of track.
9. Friction between rail and vehicle for each vehicle.

2.7.3 Dynamics

Each of the specific car types shall be modeled appropriately for its contribution to train dynamics and for its interaction with the required on-board systems. The scope of the Train performance parameters required to implement the model shall be identified by the simulator Contractor. To be able to allow for future modifications and upgrades to the new equipment the train performance data shall have to capability to be modified and retained.

2.7.4 Traction Modeling

The traction and power model shall accurately simulate the operation of the real system as a function of operator's commands and adhesion conditions.

The spin/slide control and wheel-slip systems for each type of equipment shall be modeled.

2.7.5 Friction Brake Modeling

The M-4 models shall be based upon an air brake system simulating a trailing consist of up to 8 cars. The effects of dynamic and air brake blending shall be modeled. When a simulated fault of the propulsion system is present, dynamic brake blending will be replaced with a friction brake only model.

The B-4 models shall be based upon an air brake system simulating a trailing consist of up to 5 cars. The effects of dynamic and air brake blending shall be modeled. When a simulated fault of the propulsion system is present, dynamic brake blending will be replaced with a friction brake only model.

The N-5 model shall be based upon an air brake system for the equipment simulating a trailing consist of up to 2 cars. The effects of dynamic and air brake blending shall be modeled. When a simulated fault of the propulsion system is present, dynamic brake blending will be replaced with a friction brake only model.

The Single and Double End LRV models shall be based upon an air brake system for the equipment simulating a trailing consist of up to 2 cars. The effects of dynamic and air brake blending shall be modeled. When a simulated fault of the propulsion system is present, dynamic brake blending will be replaced with a friction brake only model.

The effects of correct operation and failure modes of the wheel slip prevention system shall be modeled.

2.7.6 Other Components

A general friction model shall include static friction, and friction forces proportional to speed. Forces due to gradient of the track shall be included in the dynamic model on a vehicle by vehicle basis. A geometric track model shall be precise enough to be able to calculate all of the forces applied to the train and determine its movements.

2.8 SIGNAL SYSTEMS MODELING

The block signaling, CBTC signaling, cab signaling, and interlocking signaling systems shall be modeled faithfully with complete, accurate and proper functionality. These systems shall enable the operation of not only the train operated by the Trainee but also of an independent train which shall follow signals and switches, and operate in either direction at varying speeds.

2.9 SOFTWARE DELIVERABLES

2.9.1 System Software

The software shall simulate in real-time the subsystems which determine the behavior of the train and reproduce the visual, audio and sense stimuli that occur when driving. The train modeling software shall be sufficiently detailed to reproduce different configurations of the train with or without fault conditions.

The loading of a simulated line in preparation for running a scenario shall take less than five (5) minutes. The loading of a scenario once a line has been loaded shall be less than twenty (20) seconds.

The simulator system shall have levels of access protection that shall prevent the use of the cab simulator and its functions at several levels. The Contractor shall establish a software development plan which shall be developed to follow all relevant standards and conventions.

The Contractor shall supply a back-up copy of the pre-programmed training exercises in CD or DVD format to be used in case of system failures or data loss.

2.9.2 Training Exercises

The Training Simulator shall include a library of pre-programmed training exercises that can be selected from the Instructor’s Workstation. The training exercises shall be tested and factory loaded prior to the delivery of the Training Simulators.

The Training Simulator shall include the following training exercises:

1. Basic train handling (e.g. equipment set-up and shutdown procedures, propulsion and braking scenarios, reversing, etc.).
2. Entering and exiting yard and shop areas.
3. Arriving and departing stations.
4. Grade crossing situational awareness (where applicable).
5. Interacting with disabled equipment.
6. Traversing work zones.
7. Handicap passenger boarding and alighting scenarios.
8. Intervening track operations.
9. Common signal violations.
10. Center track station stops.
11. Night driving conditions.
12. Slippery Rail operating conditions.

When an exercise is selected the Instructor shall be provided with a description of the activity and the suggested teaching points. A description of all training exercises with the accompanying teaching points shall be included in the training documentation.

The Instructor shall be able to insert Instructor initiated events, variable conditions and vehicle defects and failures into the training exercises. The Instructor shall be able to use the pre-programmed training exercises as templates to create new training scenarios. All pre-programmed exercises shall support the specified customization of the virtual environment.

2.9.3 Defect and Failure Scenarios

The Training Simulator shall enable the Instructor to present the Trainee with a variety of vehicle defect and failures scenarios during a driving simulation. Defect and failure scenarios shall include, but are not limited to:

1. Propulsion and braking failures.
2. Loss of traction power situations.
3. Interlock failures.
4. Door failures.
5. Low voltage failures.
6. Air related failures.
7. Improperly inflated air springs.
8. Over-riding buffers.
9. Cab makeup failures.
10. Cab signaling failures.

11. Loss of radio communications.
12. Coupling and pushing/pulling of disabled equipment.

Defect scenarios shall also include external equipment and system infrastructure, such as:

1. Track switch failure.
2. Signal malfunction (Wayside and Cab Signaling systems)
3. Roadway Worker Protection failure.
4. Damaged or broken rail components.
5. Loss of catenary or third rail voltage.
6. Damaged, broken, or missing overhead components

2.9.4 Custom Designed Scenarios and Training Exercises

The Contractor shall provide a user-friendly Windows-based authoring software package that will enable the development of custom designed training exercises. The authoring software shall be installed on the Scenario Development Workstation.

The authoring software shall enable Instructors to create new and modify existing training exercises using templates and simple mouse and keyboard commands such as, click and drag, and save as. The authoring software shall enable Instructors to create training exercises based on actual incident scenarios involving rail equipment and other vehicles, stationary objects, buildings, pedestrians, moveable objects, event recorder data, incident/accident reports, video surveillance footage, and the results of investigations.

Use of the authoring software to create new training exercises on the Scenario Development Workstation shall not interrupt or interfere with active training simulations. Completed custom designed training exercises shall be stored in the training exercise library for ease of use. The training exercise library shall have sufficient storage capacity to meet the SEPTA's need for pre-programmed and custom designed training exercises.

The Contractor shall supply Instructor training, as well as complete, easy-to-use instructions for the use of the authoring software. The Contractor shall provide an additional copy of the authoring software for back-up protection to be used in case of system failures or data loss.

The ability to create new special events/effects that can be implemented along the right-of-way, various testing scenarios and other elements of a fully functional computer graphics-based Training Simulator shall be provided. This software shall be installed on the Scenario Development Workstation. All tools, programs, and software shall become the property of SEPTA, and SEPTA shall have all rights, including the right to modify the software as it wishes.

2.10 SYSTEM HARDWARE

With the exception of the cab equipment provided which is unique to SEPTA or replicated by the Contractor, all simulator system hardware shall be commercially available items which shall facilitate changes, upgrades and repair. This includes among others: PC's, 3D graphic cards, and sound cards which shall be readily available from a number commercial sources.

Each Training Simulator shall be equipped with diagnostic capabilities to ensure that each control (Master Controllers, Brake Valves, Switches, etc.) functions as intended and within tolerance. These self-diagnostic capabilities shall include all symptomatic sensors, devices, and methods necessary to determine when performance of the monitored system is deteriorating to the point where system or component maintenance is imminent and/or required.

2.11 RELIABILITY

The Contractor shall prepare and maintain a Reliability Program Plan.

The Reliability Program Plan shall be submitted within 90 days from Notice-to-Proceed. **[CDRL 2-02]**

A simulator shall have a mean time between failure (MTBF) rate of no less than 1,500 hours for failures which cause the simulator to be incapable of operating as intended.

2.12 MAINTAINABILITY

The Training Simulators shall be designed and constructed to meet specified maintenance requirements. The Training Simulators shall be designed to operate an average of 1,500 hours per year.

The use of modules, self-diagnostics, quick-disconnects, and similar devices shall be maximized to facilitate component exchange and off-simulator repair of defective components.

Equipment layout and access points shall be coordinated to provide ready access for maintenance and inspection purposes.

The Contractor shall show during design reviews the layout and ease of maintainability of each item on the Training Simulator to ensure specification compliance. SEPTA reserves the right to witness the installation and removal of equipment. Equipment accessibility review shall specifically be included in FAI (First Article Inspection). Access to major components shall be designed for ease of replacement.

The Contractor will be responsible for software quality and maintenance of compatibility in the event of operating system or hardware upgrades. Should any part become obsolescent during the warranty period, the Contractor must provide either sufficient spares to support the maintenance of the

simulator for the life cycle expectancy of the systems or provide an equivalent and compatible substitute. The cost shall be borne by the Contractor under these circumstances.

END OF SECTION

3 MATERIALS AND WORKMANSHIP

3.1 SOFTWARE AND SYSTEMS

3.3.1 General

The major goals for this section are to assure that these software systems are complete, reliable, require few if any changes late in the development cycle, are provided on schedule, and are changeable in the future without compromising design integrity. To achieve these goals, plans are needed early in the project; the requirements for software must be analyzed; and designs developed that meet all the requirements.

Documents shall need to be read by numerous people during development and in the future for problem analysis and changes. It is important therefore, that all documentation be easily and unambiguously readable.

The requirements of this section pertain to all Suppliers providing software (including Programmable Devices). If the Contractor shall supply software, excluding commercial off the shelf software, for this project then they shall also be considered a Supplier and shall also be subject to the requirements of this section pertaining to suppliers.

The software must be treated as an integral part of the total system design and shall be reviewed as part of each design review for the corresponding systems.

3.3.2 Documentation

For non-commercially available software, thorough and accurate software documentation–shall be submitted by the Contractor for Engineer approval. Sufficient documentation shall be provided to permit the Engineer to fully comprehend and analyze the operation of the equipment in which the software is to be installed; and to enable SEPTA to maintain and modify the software to correct problems, adapt it to changing requirements, add features, and port it to a new hardware platform. The Contractor shall define a single software documentation methodology for the project, subject to approval by the Engineer, and require all Suppliers to comply with it. If Computer Aided Software Engineering (CASE) tools are used which automatically generate documentation, they shall be consistent with the Contractor's documentation methodology. The Contractor shall provide descriptions to enable the Engineer to understand the documentation methodology. Software documentation training for specialized CASE tools shall be included within the formal Training Program. Documentation for non-commercially available software shall be divided into two categories, subject to approval by the Engineer. Application-specific software (developed or adapted specifically for this Contract, or newly-developed software that is intended for use on other applications as well) shall be fully documented in accordance with all requirements of this Technical Specification. Application-independent software of an

existing, service-proven design (fixed system software that is used in multiple applications (e.g., operating systems), or software that is encapsulated in a replaceable component (e.g., intelligent power modules)) may be exempt from certain Specification requirements, as approved by the Engineer.

3.4 SYSTEMS REQUIREMENTS

3.4.1 General

The Contractor shall be responsible for the overall design and for the integration of the systems into the complete system. Each subsystem is then designed and documented by the supplier with the Contractor reviewing the designs and testing the completed systems.

3.4.2 Testability

All features and functions of software systems shall be testable on a systems level. Specific approval is required for any feature that is not testable on a systems level.

All Test Plans and Procedures shall be submitted for approval prior to conducting the tests.

3.4.3 Software Activities

The Contractor, as systems and software integrator, and Suppliers who are providing processor-based products shall have a mature software development process.

The Contractor and Suppliers must plan the activities they intend to perform in order to provide the required software and related documentation. These plans must be documented and submitted to SEPTA so agreement can be reached regarding them. Plans must include schedule and resource allocations sufficient to meet the submittal requirements of the Technical Specification. Progress shall then be monitored according to the plan to assure on-time delivery and assure the software meets all requirements.

SEPTA shall be provided with sufficient documentation to fully comprehend the operation of the Training Simulator or Workstation in which the software is to be installed. The documentation shall describe how all requirements shall be met. Software documentation shall be included within the formal Training Program. Submissions shall also conform to the requirements of the procurement contract documents.

3.4.4 Operating Systems and Languages

Software may be written in a high or low level language although high level languages are preferred. The language, and its implementation for the selected microprocessor system, shall be commercially available in English. No proprietary languages or code generating systems shall be allowed. All languages and operating systems must have an acceptable installed base and be approved.

3.4.5 General Market Software

Some software supplied under this procurement may be purchased by the Suppliers from external sources and commercially available to a wide variety of users. Examples include operating systems and data base software. The Contractor shall submit for approval a list of software that is commercially available to the general public and which the Contractor and Supplier would like to be considered Commercially Available (CA) for this project. This category does not include Supplier software.

For Commercially Available software, software documentation requirements are limited to the following:

1. The original data storage/transfer media (CD-ROM or DVD), functional and usage details
2. All provider manuals
3. Licenses required for SEPTA site use

The requirements and interfaces shall be documented. References to specific sections of the provider's documentation shall be included for all requirements. The Contractor shall incorporate training on how the software is to be used in the specific situation for which it was provided as part of the Training Program.

3.4.6 Time and Date Processing

All systems provided under this procurement, whether acting separately or in combination, must properly process all times and dates within the required span of years from 2000 to 2100 inclusive. This includes all software as well as Development Systems, Operating Systems, and Workstations.

The Contractor and Suppliers shall be required to provide robust designs and to establish, through both analysis and test, that the product shall process times and dates correctly. An example of a design that may not correctly process dates throughout the required range is storing time as seconds past 1-1-1970. This technique must either not be used or, if used, must be extended to correctly process all required times and dates.

3.4.7 Hardware Platform

Microprocessor-based systems shall be based on an established family of microprocessors in wide use in the control system industry. They shall be supported by a full range of software development languages and diagnostic programs. Any use of commercially-available computer boards must be specifically approved. Such approval shall be based upon a technical review of the product, product documentation, and a commercial assessment of product availability.

3.4.8 Configuration Control

The Contractor shall develop and maintain a Software Configuration Control Plan (SCCP) for tracking software changes relative to the Training Simulators and Workstations. The Contractor shall include in the plan a data base management system capable of maintaining the history of all software and status changes making it possible to determine which versions currently resides in which simulator or Workstation, and also which versions were used in the past. The data base management system shall be capable of generating various reports showing the configuration of each simulator or Workstation in terms of software history and status. The Contractor shall make these reports available to SEPTA.

The SCCP shall be submitted for approval. **[CDRL 3-01]**

The Contractor shall submit a final software configuration for each Training Simulator and Workstation at the time of acceptance or conditional acceptance in an electronic format as approved. **[CDRL 3-02]**

All software shall be identified by a name and a version number. The name shall identify the equipment into which the software is installed. Every change to software shall be reflected in an update to the version number.

END OF SECTION

4 TESTING

4.1 GENERAL

As part of the production of the Training Simulators under this Contract, the Contractor shall be responsible for a comprehensive series of tests to be performed to verify both the suitability of design and functionality of each Training Simulator and Workstation. These tests are to be performed to ensure compliance with Specification requirements, confirm the elimination of deficiencies, and to provide data on Training Simulator operating characteristics.

The tests and any required adjustments to be performed are grouped into two classifications: Pre-Delivery Conformance and Acceptance Commissioning Tests. Whenever test requirements overlap, the more comprehensive shall govern. Pre-Delivery Conformance Tests comprise completed Training Simulator level testing at the Contractor's facility "pre-delivery" to demonstrate conformance with Technical Specification and baseline configuration requirements prior to delivery. The Acceptance Commissioning Tests consist of tests to be performed on each Training Simulator and Workstation by the Contractor at SEPTA's facilities to demonstrate conformance with the Technical Specifications and as a condition for Acceptance.

The Contractor shall also be responsible for providing assistance and expertise during performance of tests and for preparation of related test reports. It shall be the responsibility of the Contractor to develop procedures for the Training Simulator tests to be conducted. The Contractor shall perform all tests under Engineer observation. All contractual tests shall be conducted in accordance with Engineer approved test procedures. Testing activity scheduled and/or conducted before test procedure approval will be at the Contractor’s risk.

4.2 TEST PLANS AND REPORTS

4.2.1 Master Test Plan

The Contractor shall submit to the Engineer for approval a Master Test Plan as described in Section 1.6.6.3 and elsewhere in the Specification covering all tests and adjustments listed in or otherwise required by this Specification. The Master Test Plan shall be submitted to the Engineer for review and approval no later than ninety (90) calendar days after the Notice to Proceed and revised within thirty (30) days of any change in plans. **[CDRL 4-01]**

The Master Test Plan shall include, and differentiate between Pre-Delivery Conformance Tests and Acceptance Commissioning Tests. The frequency and proposed schedule for each test shall also be included. The Test Plan shall cover all Suppliers and tests to be completed at their plants, all Contractor tests to be completed at its plant prior to issuance by the Engineer of a Release for Shipment document and all testing to be conducted on SEPTA property prior to issuance by the Engineer of a Certificate of Acceptance.

It shall include a schedule showing the sequence in which type test will be performed, and the time and place of each test to be performed.

This document shall be updated if revised and presented as an attachment to the program meeting minutes showing the status of each test procedure, test, and associated report summarized in a spreadsheet format.

The Contractor shall test all functions and validate performance to assure compliance with all technical requirements. Functional tests shall be performed to approved procedures. The results shall be documented. Final inspection shall not be permitted until functional testing is completed and successful.

The Inspection plan and the Master Test Plan shall be administered by the Contractor's Quality Assurance Department. It shall be the responsibility of the Quality Assurance Department to ensure that all inspection and test requirements have been met, inspection and test data is complete and accurate, any follow up or corrective action that may be required has been completed, and all final reports are complete, accurate, and Specification compliant.

4.2.2 Test Procedures

The Contractor shall prepare a detailed test procedure for each conformance test and for any other tests conducted by the Contractor in connection with their own quality assurance program. **[CDRL 4-02]** Each test shall be a separately controlled document and identified by its own number, title, and revision. All revisions shall be submitted to the Engineer for approval. A history of test revisions and changes shall be maintained and recorded within the test document. All tests must be written in an instructional form describing the full activity of each test step and written in duplex numerical form (similar numbering system as seen in this Specification). All special tools and/or equipment to be used must be specified within the test document. The test procedures shall identify all settings and calibrations.

Test procedures shall be delivered to SEPTA for approval at least 30 days prior to the test date allowing the Engineer at least fifteen (15) working days for initial review with sufficient remaining time for the Contractor to modify a rejected procedure and resubmit for approval a minimum of five (5) working days prior to testing covered by the procedure.

The procedures for these tests shall be continually updated. The basis for changes to these procedures shall be the feedback from both the Contractor and the Engineer. The procedures may be expanded to include checkpoints in areas which have proven to be troublesome. All test procedure revisions shall be subject to the Engineer's approval. In the event a test is revised, the Contractor shall supply a copy of the test reflecting approved changes, and the upgraded revision status to replace the existing test.

Each individual test shall be accompanied by a separate test results sheet. Each step of the test requiring a specified result or measurement shall be included and identified by the duplex numeric step number

referenced in the test document. Areas shall be provided for recording actual values produced during the test where needed. In addition, pass/fail criteria and associated tolerances shall also be shown in parenthesis near the space available for recording the actual value. Each test sheet shall be identified by the associated test number and revision. Areas shall also be allocated for the date, the simulator or Workstation identification and serial number, test status (accept/reject), and signature areas for the test technician, Contractor QC, and SEPTA representative.

Software test procedures shall include test cases designed to uncover software errors as appropriate.

Test results shall not be accepted by the Engineer without an approved procedure. Supplier test reports and procedures shall be approved by the Contractor prior to submittal to the Engineer. No test will be considered completed until a test report has been received and approved by the Engineer.

4.2.3 Testing Notification

Except where otherwise indicated, fifteen (15) working days' notice shall be provided prior to any test. The Engineer will at their option witness all tests.

4.2.4 Test Documentation

Within seven (7) days of the completion of each test, the Contractor shall submit a written report of each test including copies of all test data to the Engineer for approval. **[CDRL 4-03]** The Contractor's Quality Control Department shall certify all test results prior to submission to SEPTA. In every case, the report shall include a description of the test, all raw data collected in the test, and a summary of the results in a form that can be directly compared to the Specification.

Should the test procedure and/or report be inadequate and not meet the requirements of the Specification, the Engineer reserves the right to require additional plans, procedures, details, and schedules to assure that the test program or report is adequate and does meet the Specification requirements. The approval of the Engineer does not in any way relieve the Contractor of responsibility for the adequacy of the test program within the scope of this Specification.

As a minimum, every report shall include:

1. Description of the test.
2. Date and location of the test.
3. Identity of person(s) conducting, witnessing, and/or inspecting.
4. Identification and serial number(s) of equipment tested.
5. Pass/fail criteria.
6. Any other data necessary to support the test results.
7. A summary of the results in a manner that can be directly compared to the Specification.

8. Any deviations from the test procedures, discrepancies in test results, and corrective actions.

All test procedures and reports shall be supplied by the Contractor in a separate binder and submitted to the Engineer for review and approval prior to acceptance of each simulator or Workstation. **[CDRL 4-04]** The master test plan shall be included in this binder.

4.2.5 Testing and Rework

When test results indicate failure to comply with Specification and acceptance requirements, equipment rework shall be performed, followed by subsequent retest, until compliance with the stated requirements is achieved.

To be considered that all test requirements have been met, each individual test must demonstrate that the entire set of prescribed criteria has been met at that time. If a test fails to do so, then the individual test shall be rerun in its entirety. SEPTA may, at its discretion, waive portions of the rerun test.

END OF SECTION

5 PUBLICATIONS & TRAINING

The Contractor shall be responsible for providing training to SEPTA instruction staff and manuals for the simulator. This shall include potential maintenance and repair manuals for the hardware supplied, as well as guides and tools to create new test or operating scenarios. Training for all aspects of operation, maintenance, troubleshooting and creation of additional scenarios or tests shall be included.

The Contractor shall submit a detailed functional description of the Training Simulator. **[CDRL 5-01]**

5.1 GENERAL

The Contractor shall provide all documentation and training necessary to undertake simulator implementation and to allow SEPTA to efficiently use the system. The scope of this training is to be agreed with SEPTA.

5.2 DOCUMENTATION DELIVERABLES

The Contractor shall provide two (2) complete copies of all training documentation. **[CDRL 5-02]** The Training Simulator training documentation shall include, as a minimum:

1. A detailed Training Plan consisting of an overview of the proposed training, with descriptions of the documentation provided and the individual training modules.
2. A user's manual detailing the operation and maintenance of the Training Simulator.
3. A detailed Instructor's guide that includes training objectives, lesson plans, exercises and scenarios, and best practices for incorporating the Training Simulator into the SEPTA's traditional Railroad Division equipment instruction.

The training documentation shall conform to the current SEPTA Railroad Division equipment configuration and shall be updated to include the information/material stipulated in this specification. The training documentation shall be designed in such a way as to allow the SEPTA to deliver on-going, sustainable instruction to its employees after the Contractor has completed the train-the-trainer sessions. Computer-based training modules on CD-ROM may be used to supplement and expand the items listed in above.

SEPTA reserves the rights to use, reproduce, and modify any training documentation and multimedia productions as it deems necessary for further instruction of SEPTA personnel.

5.3 TRAINING DELIVERABLES

The Contractor shall provide an SEPTA-approved User Training Program. **[CDRL 5-03]** This program shall provide adequate coverage to insure safe and satisfactory operation, servicing, troubleshooting and maintenance of the Training Simulator and all other furnished equipment. The Training Program shall be submitted to SEPTA's Training Department for review and approval no later than sixty (60) calendar days prior to the start of User Training.

The Contractor may assume that SEPTA's personnel have the basic skills pertinent to their positions, and a high school education. When creating lesson plans and content, the Contractor shall also assume that such students will be new to the Training Simulator environment and its associated systems. Instructional content shall be sufficient to include the context of the subject matter along with theory of operation, troubleshooting, corrective actions for repairs and preventative maintenance instructions.

Upon completion of the training the student shall not only have a basic understanding of the subject matter, but also be well versed in how to obtain any needed information from the manuals. The Training Program shall be conducted in English. Instructors shall have a good command of the technical English language used in the North American transit industry.

Upon the conclusion of each training unit, the Contractor shall have all participants fill out a questionnaire concerning the Program's strong and weak points, and suggestions for improvement. These suggestions shall be incorporated, as appropriate, into the Training Program. The instructors used by the Contractor shall be familiar with SEPTA's operation to a degree appropriate for the particular material being presented, knowledgeable on the specific topic being presented, and have full understanding of the Training Simulator. They shall be totally prepared to present the course material, including full responsibility to have available all audio-visual aids such as projectors, screens, flip charts, etc. necessary to present their course material. SEPTA reserves the right to check the qualifications and/or references of the proposed instructors and also to reject for cause any instructor not believed to be adequately qualified.

The formal classroom instruction shall be conducted in a suitable classroom furnished by SEPTA on its premises, as required by SEPTA. Informal field instructions may also be conducted on SEPTA's property at its discretion.

The Contractor shall update all instruction material upon completion of the warranty period to cover any changes, modifications or upgrades to the Training Simulator and associated hardware and software performed after delivery. Any inconsistency or incorrect information uncovered during the instruction period shall be immediately corrected and formally submitted to SEPTA in the form of replacement drawings, schematics, multimedia aids, lesson plans, manuals, schematics and changes in documentation.

Training shall be provided on-site. The course agenda with contents description and length of time required shall be supplied thirty (30) days in advance for approval by SEPTA. The training shall begin within ten (10) working days of SEPTA's site acceptance of the Training Simulator.

5.4 INSTRUCTOR TRAINING

The Contractor shall submit a comprehensive train-the-trainer package to SEPTA’s Training Department for review and approval by no later than sixty (60) days prior to the start of Instructor Training. **[CDRL 5-04]**

The Training Simulator shall be delivered with all of the necessary training modules, scenarios and exercises completed and modified to SEPTA’s requirements. Instructor training shall be conducted immediately following the successful installation and commissioning of the Training Simulator. The Contractor shall provide a competent and experienced Instructor to deliver the Training Simulator train-the-trainer sessions. The train-the-trainer shall take place at a location determined by the Training Department.

The train-the-trainer program shall ensure that Training Department Instructors have the competence to:

1. Operate, maintain, and trouble-shoot the Training Simulator.
2. Conduct training sessions using the Training Simulator.
3. Assess Trainee performance on the Training Simulator.
4. Use the authoring software to develop and modify training exercises.

This Train-the-Trainer program shall include classroom instruction and use of simulators. The time required for this instruction shall be at least as long as each of the training. Student and Instructor Guides must be used. Multimedia visual aids shall be included. Production of all training materials and multimedia visual aids will be subject for review and acceptance by SEPTA via the Train-the-Trainer program.

5.5 MAINTENANCE TRAINING

Theory of Operation, Troubleshooting and Repair shall be presented to the appropriate qualified maintenance personnel. **[CDRL 5-05]** This course shall be divided into subsets for equipment subsystems. Each subset shall include a detailed system description, including all components, their function and operation; adjustments and testing; disassembly and assembly; and removal and installation of the components on the Training Simulator. Special tooling and test equipment necessary to service and maintain each system shall be used, and shall become the property of SEPTA upon the conclusion of the Training Program. Time for each subset shall vary in length.

5.6 CONTINUING TRAINING

SEPTA's Training Department shall have the right to record whichever portions of the Training Program it desires for future SEPTA training use.

A complete set of all materials used by the Contractor during the Training Program, including lesson plans, training aids, manuals, mock-ups, special tools, displays and all other components used shall be presented to SEPTA within thirty (30) days of conclusion of the complete Training Program, which shall be properly revised and updated by the Contractor to reflect all equipment modifications until the end of the warranty period. **[CDRL 5-06]**

In addition to the above, the lesson plans, manuals, and training aids shall be provided to SEPTA on electronic media in accordance with Section 5.1. **[CDRL 5-07]**

END OF SECTION

6 TECHNICAL SUPPORT AND SOFTWARE UPGRADES

6.1 GENERAL

The Contractor shall provide full technical support for the Training Simulator and all of its components and peripherals for a two-year warranty period. The Contractor shall supply and install all software upgrades relevant to the Training Simulator for the two-year warranty period.

At the end of the two-year warranty period the Training Simulator and its components, Spare Parts and Peripherals shall be functioning correctly with all the appropriate upgrades, revisions and modifications installed. **[CDRL 6-01]**

6.2 TECHNICAL SUPPORT

The Contractor shall supply a detailed Technical Support Plan for the Training Simulator. **[CDRL 6-02]** The Technical Support Plan shall include the following information, as a minimum:

1. Contact information for technical support (telephone numbers and email addresses).
2. Guaranteed response times for technical support (minimum 48 hours).
3. Methods and options for providing technical support (system restore disk, internet connection, email, site visits, etc.).
4. The typical software upgrade cycle.
5. The method for completing the software upgrades.

All Training Simulator maintenance and software upgrades shall continue to support the customization stipulated in this specification. The Contractor shall provide specific SEPTA personnel with training for general maintenance and troubleshooting practices for the Training Simulator. The Contractor shall maintain a database of Training Simulator problems and technical support requests initiated by the SEPTA. This database shall be used to determine the reliability of the Training Simulator and provide the ability to track any technical issues that may arise.

6.3 INTERNET SUPPORT

The Training Simulator shall be designed to operate using a dedicated secure link to the Contractor's factory via the internet that utilizes SEPTA's VPN infrastructure and/or network. The dedicated secure internet link shall be used for software upgrades, troubleshooting, system diagnostics, and maintenance. The Contractor shall ensure the dedicated internet link is secure and protected against illegal access.

The Contractor shall comply with all of SEPTA's rules and regulations governing the use of the VPN connection.

The Contractor shall provide details for the proposed measures to ensure the security of the dedicated internet link. **[CDRL 6-03]**

END OF SECTION

APPENDIX A: CDRL MATRIX

CDRL Number	Title	TS Section	Description	Date Required
Section 1	**SCOPE**			
1-01	Training Simulator preparation and installation requirements	1.2.11	Contractor must provide a proposed layout as well as infrastructure and environmental requirements for SEPTA's review and approval.	Thirty (30) days after approval of Specification Review Conference MOC
1-02	Design Review Phase Proposed Schedule Outline	1.6.4	The Contractor shall submit a proposed schedule for the entire Design Review Phase.	Twenty (20) days after conference
1-03	Concept Design Phase Drawings and Documentation	1.6.6.2	Complete Series of CDP Arrangement Drawings and Related Documents shall be submitted as described.	Fourteen (14) days prior to first CDP review meeting
1-04	Detailed Design Phase Drawings and Documentation	1.6.6.3	Complete Series of DDP Detailed Drawings and Documents shall be submitted as described.	Fourteen (14) days prior to first DDP review meeting
1-05	Publications and Training Plan	1.6.6.3	Submissions of a comprehensive Publications and Training plan as described.	Fourteen (14) days prior to first DDP review meeting
1-06	Design Review Program Complete and Appropriate Drawings Approved	1.7.1	Engineering data package that includes drawings, FAI status reports	Thirty (30) days prior to FAI
1-07	Pre-Shipment Inspection Documents	1.7.2	The Contractor shall provide complete documentation indicating that all Pre-delivery requirements have been met.	Prior to Pre-Shipment Inspection
1-08	Shipment Authorization	1.7.3	A Release For Shipment authorization must be issued before each simulator or workstation ships.	Prior to Shipment of any Simulator or Workstation
1-09	Schematic Drawings and Documents	1.8.2	Schematic Drawings and Documents shall be submitted as described.	Prior to First Shipment of each type of Simulator and Workstation
1-10	Baseline Establishment	1.9.2	Establishment of Baseline for each type of Training Simulator and Workstation.	Upon completion of DDP

1-11	Shipment Exceptions	1.9.4	A list of items not performed on each simulator or workstation and a schedule for when the work will be completed.	Prior to Shipment of each Simulator and Workstation
1-12	Program Management Plan	1.10	The Contractor shall submit for approval a Program Management Plan as described.	Thirty (30) days after NTP
1-13	Monthly Progress Status Report	1.10.1	Reports submitted monthly in accordance with the requirements of 1.10.1.	Monthly
1-14	Configuration Management Plan	1.11	Plan shall assure that the configuration of each type of simulator and workstation remains the same.	Thirty (30) days after NTP
1-15	Quality Assurance Program Plan	1.12.1	The plan shall illustrate how the Contractor and the major subcontractors/suppliers shall meet the requirements of section 1.12.1 in its entirety.	Thirty (30) days after NTP
1-16	Purchase Orders or Existing Purchase Orders Changes Submittal	1.13.1	All Purchase Orders issued shall be forwarded to SEPTA, giving a complete bill of material description. Prices may be redacted.	Prior to Shipment of First Training Simulator
1-17	Warranties, Technical Assistance, and Repair Parts Plan	1.15	A description of a Contractor-administered two (2) year plan to implement warranties and provide technical assistance and repair parts for all equipment.	Prior to Shipment of First Training Simulator
1-18	Replacement Parts List	1.15	The Contractor shall furnish a list of the type and quantity of standard replacement parts and incidental hardware.	Prior to Shipment of First Training Simulator
1-19	Master Software List	1.18.2	The Contractor shall submit a Master Software List showing all software to be used during the duration of the Contract.	Fourteen (14) days prior to first CDP review meeting
1-20	Software Upgrades	1.18.3	The Contractor shall provide a plan to for carrying out software upgrade campaigns. Manuals and software for upgrades shall be provided.	Prior to completion of the Detailed Design Review

Section 2	**DESIGN CRITERIA AND REQUIREMENTS**			
2-01	Scoring Templates	2.5.2	Contractor shall propose to SEPTA a trainee's assessment criteria available for the Instructor.	Prior to completion of the DDP
2-02	Reliability Program Plan and Preliminary Reliability Analysis	2.11	The Contractor shall prepare and maintain a Reliability Program Plan as described.	Ninety (90) days from NTP
Section 3	**MATERIALS AND WORKMANSHIP**			
3-01	Software Configuration Control Plan	3.4.8	The Contractor shall develop and maintain a Software Configuration Control Plan (SCCP) for tracking software changes relative to the Training Simulators and Workstations.	Prior to completion of DDP
3-02	Final Software Configuration	3.4.8	The Contractor shall submit a final software configuration for each Training Simulator and Workstation.	Prior to Acceptance
Section 4	**TESTING**			
4-01	Master Test Plan	4.2.1	The Contractor shall submit for approval a Master Test Plan as described.	Ninety (90) days after NTP
4-02	Test Procedures	4.2.2	The Contractor shall prepare a detailed test procedure for each conformance test and for any other tests conducted by the Contractor in connection with their own quality assurance program.	Thirty (30) days prior to test date
4-03	Test Documentation	4.2.4	No test will be considered completed until a test report has been received and approved by the Engineer.	Within seven (7) days of completion of test
4-04	Test Documentation	4.2.4	All test procedures and reports shall be supplied.	Prior to Acceptance of each Simulator and Workstation

Section 5	**PUBLICATIONS AND TRAINING**			
5-01	Simulator Functional Description	5	The Contractor shall submit a detailed functional description of the Training Simulator.	Prior to Shipment of the First Training Simulator
5-02	Documentation Deliverables	5.2	The Contractor shall provide two (2) complete copies of all training documentation.	Prior to delivery of the Training Simulator
5-03	Training Deliverables	5.3	The Contractor shall provide an SEPTA-approved User Training Program.	Within ten (10) days after acceptance of training simulator
5-04	Instructor Training	5.4	The Contractor shall submit a comprehensive train-the-trainer package.	Ninety (90) days prior to Instructor Training
5-05	Maintenance Training	5.5	Theory of Operation, Troubleshooting and Repair shall be presented to the appropriate qualified maintenance personnel.	Within thirty (30) days after acceptance of training simulator
5-06	Continued Training	5.6	A complete set of all materials used by the Contractor during the Training Program.	Within thirty (30) days of conclusion of the complete Training Program
5-07	Training Document	5.6	All training documentation shall be submitted in electronic format.	Within thirty (30) days of conclusion of the complete Training Program
Section 5	**TECHNICAL SUPPORT AND SOFTWARE UPGRADES**			
6-01	Training Simulator Configuration and Operability	6.1	At the end of the two-year warranty period the Training Simulator and its components, Spare Parts and peripherals shall be functioning correctly with all the appropriate upgrades, revisions and modifications installed.	End of Warranty Period
6-02	Technical Support Plan	6.2	The Contractor shall supply a detailed Technical Support Plan for the Training Simulator.	Prior to delivery of the Training Simulator

6-03	Security	6.3	The Contractor shall provide details for the proposed measures to ensure the security of the dedicated internet link.	Prior to delivery of the Training Simulator

END OF SECTION

ATTACHMENT 1: SEPTA TRACK CHARTS

PDF FILE CONTAINING SEPTA TERRITORY TRACK CHARTS ATTACHED. FOR REFERENCE ONLY. UPDATED TRACK CHARTS TO BE PROVIDED DURING CONCEPT DESIGN PHASE.

END OF SECTION